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UPON THE CONSTITUTION OF BINARY ALLOYS.

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HISTORICAL INTRODUCTION.

In our museums and collections may be found metallic weapons, coins and utensils of various sorts whose antiquity is undoubted. Many of them long antedate the Christian era, and show that the people of those remote times and civilizations had an empirical knowledge of the art of metallurgy in both its branches, *i. e.*, they knew how to extract metals from their ores, and they knew how to fit them for use. To be sure, some metals occur native, but it is impossible to suppose that all the metals used by the ancients were of this kind. In the Old Testament scriptures, gold, silver, copper, iron, lead and tin are mentioned, and also brass, though copper or bronze is probably meant.

The art of refining in furnaces seems to have been known long before the Christian era. Pliny and Dioscorides give fairly accurate accounts of the smelting operations of their times, but do not explain or attempt to explain the chemistry of these processes. The behavior of mercury and gold—that is, the general facts concerning amalgamation—was known long before Pliny's time, and cupellation, as a refining process for gold, was certainly practiced before the second century B.C. The method of separating silver from gold by a process of cementation, in which the silver was "sweated out" by heating the gold silver alloy with salt and alum-shale, originated before the time of Christ, and is mentioned by Pliny.

Cupellation for the sake of quantitative estimation of gold and silver in alloys seems to have been first introduced by Roger, Bishop of Salisbury, in the reign of Henry I, early in the twelfth century. It must be remembered that in those days, and even for centuries later, the right to coin money was conferred by contract upon private individuals. It had also been the custom with those favored gentlemen to amass great fortunes by debasing the coinage of the realm and to escape punishment by occasional costly gifts to their king. When Roger applied cupellation as a method of assaying coins, the coiners were called to account, and of fifty examined, only four escaped punishments, which were doubtless more effectual than humane.

We have already mentioned bronze and gold-silver alloys; the cupellation process implies the existence of lead-gold and lead-silver alloys. Tin, though of relatively early discovery, was known in its alloys still earlier than as a distinct metal. Its alloys with lead were used as solder by the Romans. Brass, the most useful of all alloys, save only steel, was described by Aristotle, but was not recognized as an alloy. The people of his time knew that when copper was fused with a certain earth (zinc ore) its color was changed. It became more yellow and golden in appearance, and this phenomenon doubtless had considerable influence in strengthening the faith of the alchemists in later centuries in the doctrine of the transmutability of metals.

In succeeding centuries, such metallurgists as Geber, Biringuccio and Agricola wrote, speculated and experimented much upon the phenomena of reduction and oxidation of metals. Nearly three hundred and fifty years ago the Royal Society took up the problem of the oxidation of molten lead in air, and discovered that its increase in weight was due to some constituent abstracted from the atmosphere. During all the centuries down to the phlogistic period, other metals were discovered and other alloys produced either by chance or design; and the profound changes which metals undergo when heated together were probably recognized by the shrewd observers of all ages. In the phlogistic period, which may be said to comprise the end of the seventeenth and most of the eighthteenth centuries, metallurgy had so advanced that a crude explanation of the distinction between wrought-iron, cast-iron and steel had been made. It does not appear, however, that any very decided opinions as to the constitution of metallic mixtures were advanced at this time and, indeed, one could scarcely expect that the profound questions of molecular physics, which a study of alloys involves, could have been solved or even approached before the announcement of a molecular theory of the constitution of matter, nor could it have made any progress earlier than the period of chemical reform instituted by Lavoisier, and properly known as the period of quantitative investigation.

Just at this time, however, when all conditions seemed favorable for investigating the molecular constitution of metals and alloys, Dalton announced the atomic theory and the law of simple numerical proportions. Thus, the great aim of the early chemists, that of determining the exact composition of substances, was directed toward bodies which were recognized as true chemical compounds whose composition might be expected to confirm Dalton's law. Alloys manifestly did not, in many instances, come under the provisions of the atomic theory, and hence were neglected by chemists and largely, too, by physicists. More recently the relations of physical properties to chemical constitution have attracted chemists and physicists alike, but in this

field of investigation, alloys were last to receive serious attention or, at least, to yield fruitful results. The physical methods successfully applied to bodies of other kinds failed utterly to bring to light a rational explanation of the molecular conditions existing in alloys. The solution of these problems required new methods and new apparatus. These have been slowly forthcoming, and the past decade has been most fruitful of results, and problems of inestimable practical importance and extreme difficulty have been solved.

MODERN ALLOYS RESEARCH.

With a few exceptions, the great leaders in this work are a contemporary school of English and French metallurgists and molecular physicists. In the pages that follow, we aim to give a résumé of their achievements, and to outline our present knowledge of the nature and constitution of binary alloys. There are three important factors which account for the recent progress in alloys research. (1) increased knowledge upon the subject of solutions. (2) the development of the science of matallography. (3) improvements in pyrometry. To these we might add a fourth, namely, the official recognition of the importance of investigation along these lines which, over ten years ago, led the Institution of Mechanical Engineers of Great Britain to appoint an "Alloys Research Committee," which receives financial aid from the Institution; and the Société d'Encouragement pour l'Industrie Nationale to create a "Commission des Alliages," for whose researches nearly all the railway companies of France and many metallurgical concerns contributed generously.

For advancing our knowledge of solutions we must give credit to the great physical chemists of Germany and Holland —Ostwald, Nernst, Van't Hoff, Roozeboom, and others. The microscopic study of metals seems to have originated with Dr. Sorby, an Englishman, who wrote upon the microstructure of meteoric iron as early as 1864. Only within the past ten or fifteen years has this method of investigation obtained just recognition among scientists as a valu-

able aid to metallurgical research, and not even yet has it obtained proper recognition among manufacturers. Recent progress in metallography is most nearly associated with the names of Stead, Martens, Osmond, Le Chatelier, Charpy, Roberts-Austen, Howe and Sauveur.

In the purely scientific study of the cooling curves of metals and alloys, two systems of pyrometry have given valuable results. The Siemens electrical resistance pyrometer, perfected by Callendar and Griffiths, is a reliable instrument, and, within certain limits, gives wonderfully accurate readings. For use both in the laboratory and in the factory it does not seem so satisfactory or so popular as the Le Chatelier thermo-electric couple. Not least among the advantages of the platinum, platinum-rhodium couple are, its accuracy at high temperatures, its ability to be used with small masses of heated substances, and, indirectly, its adaptability to photo-autographic recording of the temperatures indicated by such an instrument as the one invented by Sir William Roberts-Austen.

CRYSTALLINE STRUCTURE OF PURE METALS.

Before considering the constitution of alloys, it is well to know something of the general properties of metals. All solid metals are crystalline, although in microsection the individual crystals or crystalline grains may not present a simple geometrical outline. Professor Ewing, of Cambridge, has pointed out in this regard that the essential point is that the particles composing the mass of a crystal lie in one direction, *i. e.*, have the same plane of orientation. He also explains crystallization in a metal in this way: The formation of crystals must be assumed to start simultaneously at many points. The crystals grow until they touch one another; thereafter their symmetrical growth is impeded, but it is not necessary that the corresponding axes of any two of them be lying in exactly the same plane. In the case of commercial metals, more or less impure, the impurities are cast out by the growing crystals, and being, in fact, alloys of the admixed impurities with a little of the principal metal, have a lower melting point than

the pure metal. Hence they solidify last and form an investing cement which holds together the primary crystals.

THE EFFECTS OF STRAIN IN PURE METALS.

Within the elastic limit no change is noticeable upon the polished surface of a metal or alloy when the same is under stress. When, however, the plastic stage is reached, there will appear dark lines more or less perpendicular to the direction of stress. This, Professor Ewing says, is not due to fissuring, for by changing the direction of the rays which illuminate the specimen under observation from vertical to oblique, it will be seen that the erstwhile dark lines appear light, while the background has changed from light to dark. Fissures would not reflect light in any case; the permanent elongation is due to slipping of the components of the crystals past one another. The slip lines need not necessarily lie in one plane. As many as four sets of parallel slip lines have been noticed by Professor Ewing.

My colleague, Mr. William Campbell, studied this phenomenon independently at about the time that Professor Ewing was making these interesting observations. Mr. Campbell has very kindly allowed me to exhibit here for the first time some of his results. Mr. Campbell worked with tin, while Professor Ewing experimented chiefly with lead. It is very interesting to notice how completely their results agree.

Fig. 1 shows the growth of crystals in tin. Two samples were rolled and then annealed for ten days upon a hot plate, below 200° C. The annealed specimens were etched and show in a very striking manner, not only the growth of crystals, but also the different planes of orientation. The figure shows these crystals slightly reduced from their natural size. *Figs. 2, 3* and *4* show respectively the same specimen of hammered tin; 2 is the original, etched in HCl, magnified 33 diameters, oblique illumination. On standing eighteen months the appearance changed to that shown in 3, also magnified by 33 diameters, oblique; and 4 shows the effect of annealing 3 for ten days on the hot plate, but it is only magnified by 16 diameters. In *Fig. 5* we have

FIG. 1.

FIG. 2.

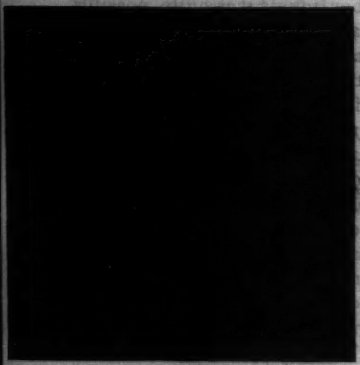

FIG. 3.

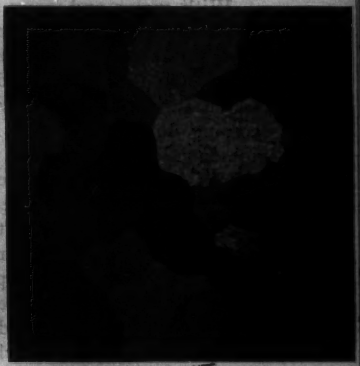

FIG. 4.

FIG. 5.

FIG. 6.

a microsection of No. 4, which shows wonderfully well lines due to strain which Mr. Campbell thinks was set up by the rapid growth. The fact that in different crystals the lines are parallel tends to confirm this view, the strain not having been manifested in a single direction. When such is the condition due to stress, a condition such as is illustrated in *Fig. 6* is set up, in which the general direction of the slip lines is normal to the direction of stress.

FREEZING-POINT OF METALS.

With water and many other liquids it is quite possible to lower the temperature to a considerable amount below their freezing-points without any separation of solid taking place. On the other hand, there is no known substance which can be heated above its melting-point without becoming liquid. When a liquid which exhibits this phenomenon of surfusion is thus cooled, and solid matter begins to separate, the temperature rises rapidly to the true freezing-point and remains constant until the whole mass is solid. The same is true of pure metals. Sir William Roberts-Austen cites an instance in which tin was cooled 20° C. below its freezing-point without solidifying. The author has frequently observed the same thing in tin and other metals, but to a less degree. In working with metals we take the first point at which solids separate as the freezing-point. For practical purposes we may consider the freezing-point and the melting-point as identical, but the latter is very difficult to determine, while the former is not. The phenomenon of surfusion need not obscure the determination of the correct point, particularly if we obtain an autographic record of the cooling curve. If we plot a typical cooling curve of a pure metal, using temperature and time as the coördinates, we obtain a curve like AB (*Fig. 7*) n which the angles are very distinct, *i. e.*, the temperature remains constant during the whole of solidification. If surfusion takes place—and it is more common in pure metals than in alloys—the curve $A'B'$ represents what happens. The temperature falls below the real freezing-point and then rises abruptly to that point and remains constant as

in AB until complete solidification. In impure metals and solid solutions the temperature does not remain constant at all, but there is a decided change in direction when solid first begins to separate, as shown in *Fig. 11*. The greater the amount of impurity, the more rounded will be the cooling curve after it has passed the first angle. Thus, the nature of this line is an indication of the purity of the material under examination. To explain surfusion, we need only remember that fusion is always attended by absorption of heat and solidification by evolution of heat. When a superfused substance begins to solidify it disengages heat, and the temperature rises until the melting-point is reached. No further rise takes place, because at

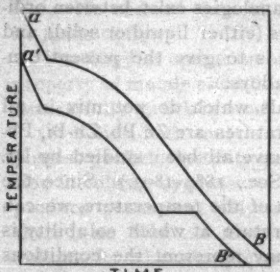

FIG. 7.

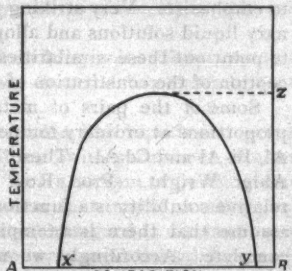

FIG. 8.

this point liquid and solid are in equilibrium. Any further change of liquid to solid or solid to liquid must be effected by abstracting or adding heat by independent means; in practice either heat is lost by radiation or is supplied by artificial warming.

ALLOYS AS SOLUTIONS.

Bearing in mind these few facts concerning metals, we are ready to consider what may take place when two metals are melted together. First, then, they may, or second, they may not, mix in all proportions. In the first instance, under proper conditions, an approximately homogeneous mass is

likely to result. In the second case, upon cooling, it will be found that the metals have separated into layers, the lighter metal on top. Leaving out of consideration for the present the metalloids, we would find upon analysis of two such metallic layers that each metal contained a little of the other in solution, just as ether and water dissolve small quantities each of the other. In the case of certain metals and metalloids, the degree of mutual solubility is negligible at ordinary temperatures, although they may be quite soluble at high temperatures. For example, M. Moissan tells us that metals of the platinum group readily dissolve several per cent. of carbon at the temperature of the electric furnace, but cast it *all* out as graphite on cooling.

It is the conception of alloys as solutions that we wish to emphasize. Very striking analogies exist between ordinary liquid solutions and alloys (either liquid or solid), and to point out these similarities is to give the present conception of the constitution of alloys.

Some of the pairs of metals which do not mix in all proportions at ordinary temperatures are Zn-Pb, Zn-Bi, Pb-Al, Bi-Al and Cd-Al. These have all been studied by Dr. Alder Wright. (Proc. Roy. Soc., 1889-1893.) Since the relative solubility is a function of the temperature, we can assume that there is a temperature at which solubility is complete. Accordingly, we may represent the conditions existing between these and similar pairs of metals by a "critical curve." (*Fig. 8*) *A* and *B* are the metals which are not entirely miscible at ordinary temperatures, but which form layers. The metal *A* contains the quantity of *B* represented by the space $A\,x$ on the composition line. Similarly the metal *B* contains $B\,y$ per cent. of *A*. With increasing temperature the mutual solubilities increase, and at the temperature z there is but one solution. Alloys represented by percentage compositions which fall outside of the curve $x\,y\,z$ are homogeneous solutions. Those whose composition are represented by percentages within $x\,y\,z$ must be considered as comparable with emulsions. They are incapable of remaining homogeneous. To such alloys Sir George Gabriel Stokes gives the name of *ideal*

(*i. e.* unreal, imaginary) alloys, while those falling outside the area *x y z* are *real* alloys.

MOLECULAR FREEDOM IN SOLIDS.

It must not be supposed that because certain bodies are designated "solid" that entire absence of molecular mobility is implied. Such an idea is far from the truth; the difference in mobility of the molecules in "solids" and "liquids" is one of degree only. On the boundary between solids and liquids substances are said to be viscous, plastic, etc. Prof. W. Spring, of Liege, demonstrated the fluidity of metals, if I may use that expression, in his famous experiments upon the behavior of metals under exceedingly high pressures—ten thousand atmospheres, more or less. He showed that by pressures alone, (1) metals can be made to flow.

The familiar operation of striking coins illustrates this property of metals and alloys. A medal has recently been successfully struck in steel.

(2) Solids, both metals and salts, like liquids and gases, possess perfect elasticity and suffer no permanent diminution in volume by pressure. Strain, torsion or bending may produce permanent deformation in a metal or alloy, but there is no "limit of elasticity" in regard to diminution of volume, for when the pressure is removed the solid expands to its original volume. An exception to this constitutes Professor Spring's third conclusion, viz.:

(3) Allotropic changes may result from pressure. Prismatic sulphur becomes octahedral sulphur, and amorphous arsenic becomes crystalline. In both these cases the second allotropic form is denser than the first, and from these and other experiments Spring argues that allotropic transformations by pressure show that matter takes the state which corresponds to the volume it is obliged to occupy. Moissan's brilliant experiments upon the production of artificial diamonds illustrate this principle.

(4) Spring showed that metallic filings are converted by pressure alone into solid masses, just as if they had been fused. Similarly, mixed filings yield alloys; for example,

brass was produced by pressing together zinc and copper. Reactions of double decomposition and the production of the highly colored regulus of Venus—Sb_2Cu_5—show that not only agglutination but also chemical combination may take place between bodies in the solid state. I have confirmed some of Professor Spring's results, but was unsuccessful in attempts to produce several such typical intermetallic compounds as $AuAl_2$, SbSn, $CuSn_4$, etc.

Prof. Sir William Roberts-Austen has also demonstrated the fact of molecular mobility in solids in a prolonged series of experiments upon the diffusion of gold into lead at temperatures varying from 250° down to ordinary temperatures. Graham showed long ago that the diffusion of gold, silver and platinum into liquid solvents, such as lead, tin and bismuth conformed to Fick's law (Roberts-Austen's Graham Lecture, Philosophical Society of Glasgow, 1900); that is, solid metals dissolve in molten ones, and diffuse against gravity, just as salts dissolve in water. Were it not for the application of this law to alloys it would not be such an easy task to prepare homogeneous alloys. For instance, with relatively little stirring, and relying mostly upon diffusion, Professor Roberts-Austen finds it an easy matter to make 1,200 ounces of coin gold alloy, the first and last pourings of which do not differ by more than $\frac{1}{10.000}$th part in fineness. The idea that interchange of matter can take place between solids is not a new one. The very antiquated cementation process used by the Hebrews perhaps 2,000 years ago for removing impurities from gold shows an empirical knowledge of the fact. Coming down to much later times, we find that Robert Boyle thought that "even gold" had its "little atmosphere;" that is, exhibits a minute tendency toward evaporation at ordinary temperatures.

The very beautiful experiments upon the diffusion of gold into solid lead which Roberts-Austen has recently reported to the Royal Society, may be summarized as follows: Gold placed in the bottom of tubes filled with lead and maintained at 250° C. (about 75° below its melting point) appeared at the top in notable qualities in a month.

At 100° C. the rate of diffusion was $\frac{1}{100,000}$th of that in just fluid lead, and in solid lead at the ordinary temperature, allowed to stand in contact for four years, unmistakable diffusion took place, but its rate is such that in 1,000 years the diffusion would equal that taking place in just molten lead in one day.

PRACTICAL APPLICATIONS OF MOLECULAR MOBILITY IN SOLIDS.

The practical applications of molecular mobility are many. We need only mention the annealing operations so common in all sorts of industries, by which means the ill effects of strain due to rapid cooling are remedied, and equilibrium is established in articles of metal, glass, enamel and other materials. The rate of diffusion of gold in lead at the various temperatures cited by Professor Roberts-Austin is an indication of the rapid increase in molecular mobility which results by very moderate changes in temperature. Steel is very sensibly annealed at temperatures more than 1,000° C. below its melting-point.

THE PHENOMENA OF SOLIDIFICATION OF BINARY ALLOYS.

Let us resume our classification of the phenomena which may result when two metals are melted together. It was stated that they may or may not mix in all proportions; now we may add that, if completely miscible, (1) chemical combination does not take place, or (2) chemical combination does take place, and one or more intermetallic compounds result.

The reality of the existence of intermetallic compounds is undoubted, yet, so far as I am aware, no mention of them is to be found in books on general chemistry. Indeed, very little is known in regard to the nature of the affinity between metals. It does not seem necessary to think that the laws applying to combination between the members of pairs of elements or radicles which are respectively electro-positive and electro-negative be equally applicable here; and our ideas of valency are seriously shattered if we attempt to reconcile them to intermetallic compounds.

The difficulties in studying such compounds are very great, because they are difficult to isolate; they are frequently quite unstable and show marked dissociation. Chemical methods of studying them are of very limited application; filtering off solidified intermetallic compounds from a still fluid metallic mother liquor presents extreme difficulties at high temperatures; and volatilization of the excess of solvent is rarely practicable. In a few cases the heat of formation can be determined, and the electrical method of comparing the potential of binary alloys with that of the more positive metal in the alloy, using as the electrolyte an aqueous solution of a salt of the more positive metal, may yield important information as to the solubility of one metal in another in the solid state. The microscopic evidence and that of the freezing-point curve are not wholly satisfactory in this regard. (See Hershkowitz, *Zeits. Phys. Chemie*, xxvii, p. 113, and Laurie, *Trans. Chem. Soc.*, 1888, p. 104.)

Cooling-curves.—During the cooling of a molten alloy various constituents may crystallize out successively; definite compounds, which are stable only at high temperatures, may split up into simpler constituents or new compounds, impossible at high temperatures, may be formed as the temperature falls. All such molecular changes are accompanied by corresponding thermal effects, such as the disengagement or absorption of heat. It is by the accurate measurement of the temperature at which these changes take place that we obtain most valuable information in regard to the molecular movements in the mass. The Le Chatelier pyrometer used in conjunction with an autophotographic recording device seems best suited to measure and record these changes. The general principles of thermo-electric pyrometry are too well known to require discussion here. Indeed, were they not well known, I could not do better than refer to H. Le Chatelier and O. Boudouard's volume, "Mesure des Températures elevées," or to its English translation with supplement by George K. Burgess.

As there are many who are more familiar with the theory

than with actual pyrometric measurements, I will show by the accompanying illustrations the system of appliances which I used during several months when it was my privilege to work in Sir William Roberts-Austen's laboratory. The apparatus used in his own valuable researches upon steel and other alloys has been described and illustrated by Professor Roberts-Austen in the reports of the Alloys Research Committee, published by the Institution of Mechanical Engineers. The apparatus shown here for the first time differs in some respects from that described in these reports, and was in part designed for my use. The recorder, which is the only original feature, was designed by Dr. Stansfield, and constructed by the Cambridge Instrument Company. *Fig. 9* shows in the lower right-hand corner a crucible containing the alloy. In practice this is set inside of a larger crucible and surrounded by asbestos to prevent too rapid cooling. Just at the top of the crucible is seen the little fire-clay or porcelain tube, within which is placed the thermo-junction, consisting of a platinum and a platinum rhodium (10 per cent.) wire. Except at the point where their extremities are soldered together the two wires are separated by strips of mica, which also serve to prevent access of cold air to the thermo-junction. In the picture the Pt — Pt, Rd wires are just discernible leading to the "cold-junction" at the upper right-hand corner. Here they are soldered to two heavy copper leads, each lead being immersed in a test-tube filled with alcohol, and the two test-tubes are surrounded by water at the room temperature, or a freezing mixture may be used. The copper leads are connected with a D'Arsonval reflecting galvanometer—dead beat and of high internal resistance. Additional resistance is placed in the circuit; by this means the deflection produced by any degree of temperature may be cut down to any convenient angle. With considerable resistance in the circuit, the change of resistance due to heating the short portion of the couple which is encased in the fire-clay tube becomes negligible. A beam of light is thrown from the galvanometer mirror upon the horizontal slot in the front of the recorder shown in *Fig. 10*. The front view

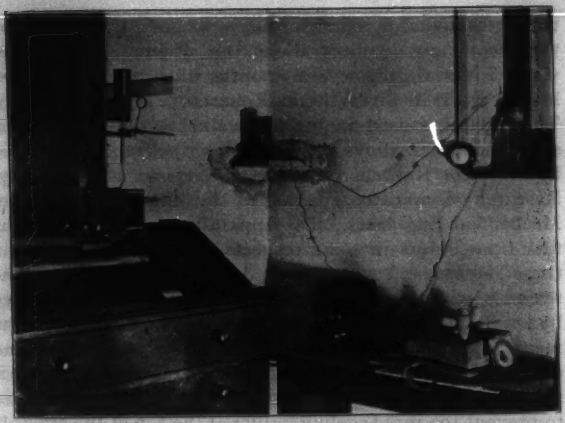

FIG. 9.

FIG. 10.

shows the slot with a centimeter scale attached. At either side is an incandescent lamp. Ordinarily but one lamp is used, a portion of its filament, shining through a vertical slit in the brass shade, is focussed by means of the small lens (attached to an arm projecting from the lamp) upon the mirror, and is reflected back to the horizontal slot, traversing it as a narrow line of light. At the back of the slot, by which light is admitted to the photographic plate, the opening is very narrow, and so the beam becomes reduced to a point of light which travels horizontally as the deflection of the mirror changes. The back view of the recorder shows a ground-glass focussing screen, which is used in getting the spot of light focussed to such proportions that its tracing on the plate shall be a slender one. Before putting the plate-holder into the carrier this screen is removed. The plate-holder carrier, clock-work, etc., require no explanation, except that the plate in descending drives the clock-work, resistance being offered by a vane whose size may be varied. There are three gears in the mechanism of the clock itself, which also assist in regulating the speed of descent of the plate to any desired rate.

Before using the instrument it must be calibrated by obtaining such fixed points as are given by the boiling-point of water (100°) and sulphur (444.53°), the melting-points of tin (232°), aluminum (654.5°), gold (1064°), and pure electrolytic copper (1083°). Not all these points need to be determined for a single calibration; three points, if determined with great accuracy, are enough. Other points may be determined by way of verification.

When the instrument is ready for use it is only necessary to insert the couple, suitably protected by a fire-clay or porcelain tube, into the molten alloy or pure metal. The beam of light rapidly moves from left to right until the thermo-couple attains the temperature of the mass, then it begins to move slowly in the opposite direction. The photographic plate is set in motion, the shutter on the front of the slot is opened, and we get a tracing known as a "cooling-curve." The vertical axis of this curve represents time, and the horizontal axis represents temperature. The type of curve

given by a pure metal has already been shown (*Fig. 7*); the same sort of curve is produced when a definite intermetallic compound or a eutectic solidifies, *i. e.*, these three kinds of substances have a single freezing-point at which the entire mass becomes solid. The nature of eutectics will be considered later; suffice it here to say that by a eutectic we mean that alloy of a series which has the lowest melting-point. Its composition is constant in any series of alloys. In *Fig. 11* the curve *AB* represents that of a homogeneous solid solution. It shows but one break, though the temperature does not remain constant during the whole period of solidification as it does with pure metals, compounds and eutectics. In *A' B'* we see a curve with two breaks; the upper

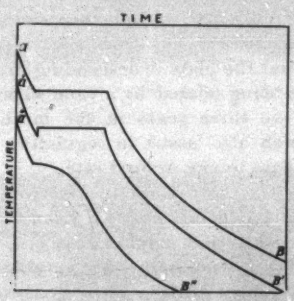

FIG. 11.

one resembling that of a solid solution, and the lower one shows the form of a eutectic. The explanation of these curves will appear as we proceed. The abrupt change in direction in *AB* occurs at the temperature at which that metal or component which is in excess begins to crystallize. As the excess of one metal solidifies the concentration of the residual fluid is increased with respect to the metal which is not in excess. The ultimate cause of the change in direction is the liberation of latent heat of solution.

As is well known, when concentrated hydrochloric acid (*i. e.*, solution of HCl gas in water) is boiled, the hydrochloric-acid gas evaporates faster than the water. If dilute

hydrochloric acid is boiled, the water evaporates relatively faster than the gas. The inevitable result is that, at a certain concentration, hydrochloric acid and water vapor leave the liquid at a rate proportional to their concentration; thereafter the composition of the liquid remains constant and the boiling-point fixed.

A somewhat analogous case is that of the solidification of two metals, *M* and *N*; either of them may be considered as the solvent. When one of them, say *M*, contains more of *N* than it is capable of retaining in the form of a solid solution, and supposing that *M* has a higher melting-point than *N*, then—though the fluid mixture may be perfectly homogeneous—on cooling, the metal *M* with the higher freezing-point, begins to solidify first at some temperature *below* its true freezing-point, for it is not pure metal, but *M* containing some *N* in solid solution. But as the temperature falls, and more of *M* separates, the residual fluid becomes concentrated with respect to *N*, and the freezing-point is lowered progressively as the excess of *M* (+ more or less of *N* in solid solution) separates.

Some students of alloys consider that at temperatures between the first solidification of solid and the point at which the residue solidifies as a whole there does not exist a homogeneous condition. They liken alloys within this range of temperature to an emulsion, to conjugate solutions, etc. The reason assigned for this is that, ultimately, the excess of solvent having crystallized, the residual metals crystallize out side by side giving the usual laminated structure of eutectics. These laminæ consist not of pure *M* and *N*, but solid solutions each of the other; each contains the maximum amount of the other which is possible at the given temperature. Now, is it necessary to suppose that these two solid solutions existed as such in an emulsified state above the freezing-point of the eutectic? To be sure, the microscope reveals a very marked separation of the alloy into two constitutents, usually with characteristically laminated structure, but these two components show no tendency to separate into distinct layers when the alloy is kept for a long time just above its eutectic point; on the

other hand, the magnitude of the eutectic structure is markedly influenced by the slowness of cooling below the eutectic temperature. Furthermore, the evolution of heat during the freezing of a eutectic is very considerable, and may perhaps be accounted for by such a decided molecular rearrangement as the formation of a laminated structure from a homogeneous fluid-mass would involve; and lastly, let me give some concrete evidence on this point, which

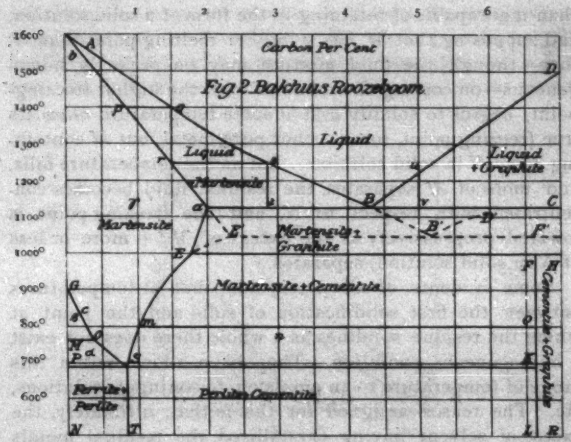

FIG. 12.

was brought to my attention by Mr. Campbell. In a lecture before the Society of Arts, of Boston, Mr. Sauveur stated: "It has been conclusively established that, in unhardened steel, at least, the totality of the carbon is combined with a portion of the iron forming carbide (FeC_3), which is then distributed through the balance of the iron." Therefore it appears that in Prof. Roozeboom's equilibrium curves of carbon-iron alloys (taken from the *Iron and Steel Institute Journal*) that the area marked Martensite (A,a,E.S.G.) in *Fig. 12* consists of a solid solution of carbide of iron in gamma-

iron. But this alloy, Martensite, containing, say, 0.89 per cent. C. is capable of splitting up at about 690° C., or nearly 800° below its freezing-point, to the beautifully characteristic structure of pearlite; accompanying this change, there is a marked evolution of heat—the critical point *Ar 1* of Osmond. If such a decided transformation can take place in solid steel, it surely ought not to be considered improbable that a similar one could take place in any alloy at the instant of final solidification when the molecular freedom is doubtless many times as great as in the example.

[*To be concluded.*]

THE HEAT OF THE INCANDESCENT ELECTRIC LAMP.

The *London Lancet* offers some very timely comments on certain popular misapprehensions regarding the incandescent electric lamp. These relate to the very common belief that the electric glow lamp emits very little heat and to the consequent carelessness with which such lamps are disposed in the neighborhood of combustible materials without knowledge or consideration of the danger thereby incurred.

The general heedlessness on this point may be observed almost everywhere in shop windows where electric lamps may be seen in close proximity to combustible goods, and the wonder is that losses by fires from this cause are not very general.

As the *Lancet* states, the electric incandescent lamp is an apparatus for the conversion of one form of energy into another. In this case, the object is to secure the conversion of electricity into light, but it is not generally known or appreciated that only six per cent. of the current energy is thus transformed, the remaining portion being transferred into heat. While the amount of heat evolved from the carbon filament is not comparable with that of a naked gas flame, it is nevertheless great enough to cause the igniting of combustible objects brought in contact with it, and the danger of accidental fires arising from carelessness in placing readily inflammable objects—paper textiles, woodwork, etc.—in contact with or in close proximity to lamps of this kind, is not imaginary, but very real.

The *Lancet* lays special stress on this point, in connection with the very general use of glow lamps in shops for the purpose of decoration as much as for illumination. When thus used, there is often no regard whatever paid to their proper and careful disposition, with the view of avoiding possible accidents from fire.

To emphasize its caution to the public the *Lancet* gives the following instructive experimental examples:

"We have found by experiment that on immersing a 16 candle-power lamp (100 volts pressure) in half a pint of water the water boils within an hour, and in proportionately less time when a 32 candle-power lamp is substituted. If again the lamp be buried in cotton-wool the wool soon begins to scorch and

ultimately to burst into flame. In one experiment which we made the bursting into flame of the wool was accompanied by a loud report due to the explosion of the lamp. It clearly appears from this that the incandescent electric lamp cannot be regarded as an unlikely means of starting a serious fire, and shopkeepers, especially those who exhibit highly inflammable fabrics, should know that there is risk in placing such goods too close to the lamp. The lamp in contact with celluloid fires it in less than five minutes, and therefore the danger is particularly obvious in the case of toy shops where electric incandescent lamps are often suspended in the midst of toy celluloid ball."

W.

SCIENCE AND INDUSTRIAL SUPREMACY.

M. Levy, writing in the *Revue des Deux Mondes*, draws the attention of his countrymen pointedly to the remarkable development of the chemical industries in Germany and indicates the cause. He takes as an example the manufacture of the coal-tar derivatives.

The total European production of these compounds is valued at 125,000,000 francs, of which Germany is credited with 90,000,000, or approximately three-fourths of the whole. Switzerland follows with 16,000,000. France and England come next with 10,000,000 and 9,000,000 respectively.

The author very properly assigns the cause of this remarkable supremacy of Germany in this branch of the industries to the systematic employment of the highest scientific skill in the German manufactories. He makes the interesting statement that a single factory in Ludwigshafen in Baden employs a larger force of technical chemists than are working at the same branch in the whole of England, and he proceeds with this form of comparison, much to the disparagement of his own country.

The Germans not only cultivate theoretical science with the utmost thoroughness in their high schools, but also have the keenness to take the discoveries of their scientific investigators and extract therefrom the greatest amount of practical utility. *Science* makes the following additional extracts from M. Levy's highly interesting paper:

"The secret of the aniline dyes was discovered in England. France took up the investigations, but it was in Germany that particular attention was first paid to their commercial perfection as regards brilliancy, permanence and cheapness. As a natural consequence, Germany now almost monopolizes their production. The same is true in respect to electricity. The monetary benefit of the researches of Lord Kelvin and the late Professor Clark Maxwell is mainly reaped by the Allgemeine Elektricitæts Gesellschaft and the great firms of Siemens, Loewe and Schuckert, which have a combined capital of 15,000,000 pounds. Almost the only chemical industry which holds its own in England is the manufacture of alkali, and this owes its success to a distinguished pupil of Bunsen's, Mr. Ludwig Mond. M. Levy points out that Bunsen and Liebig were the founders of the German chemical industry. It was Liebig who devoted his energies and influence to obtaining State aid for laboratories of technical science. From these laboratories issue annually some 800 doctors of science to undertake the direction of factories or the investigation of rare products of commercial value. Their education has been assisted by the State, and the knowledge they have acquired will be devoted to increasing, by the surest of all means, the wealth of the nation."

W.

Mining and Metallurgical Section.

Stated Meeting held April 10, 1901.

THE INSPECTION AND TESTING OF CEMENTS.

By Richard L. Humphrey,
Member of the Institute.

(*Continued from vol. clii, p. 461.*)

NORMAL CONSISTENCY.

The percentage of water to be used in making tests of setting, briquettes and pats is of the greatest importance, for upon this depends the results obtained. The paste used in these tests should be of a definite or what is called a standard consistency. The same consistency should be used for all tests.

The method, therefore, for determining the quantity of water required to give the paste a standard consistency is of the greatest importance. This consistency varies in the different European countries. In this country there is no well-defined consistency. This is because every person has a different idea of what constitutes a "stiff plastic paste."

I prefer a wet rather than a dry mixture for a normal consistency, because the more wet the paste the less danger there is of compressing the briquette; and since there is no practical method for molding briquettes under uniform pressure, a difference of density in the briquettes results, which produces decided variations in the tensile strengths.

Besides, it is much easier to thoroughly mix a wet paste, especially by hand methods.

On the other hand, the paste should not be so wet as to produce shrinkage of the briquettes after molding.

I have for many years used the normal consistency apparatus used in Germany; this is the Vicat needle apparatus in which the needle is replaced by a rod having a section of 1 centimeter and weighted with 300 grams. The penetra-

tion of the rod to a given point established the percentage of water required. At the Charlottenburg testing laboratory in Germany, it is the practice to determine the proper percentage of water to be used by mixing the cement to a syrupy paste, so that it will run from a knife (6 by 1½ inches) in long, thin threads without forming lumps.

Representing the quantity of water required to produce this condition by N, then the percentage of water (W) required to produce a normal consistency is obtained from the formula.

$$W = \frac{N + 1}{2} \text{ for neat tests, and}$$

$$W = \frac{N + 3}{4} \text{ for sand tests (one to three)}$$

This gives a consistency suitable for use with the Boehme-Hammer apparatus, and is, therefore, much dryer than is the practice in this country.

A rather crude method, yet one which gives excellent results, consists in molding the paste into a ball and dropping it from a height of 1 foot. The ball to be of the proper consistency should not flatten materially or crack. I find that this method gives results which correspond very closely to those obtained by means of the normal consistency apparatus.

This consistency is suitable for the pat, set and neat tensile tests. For sand mortars I have obtained very uniform results by calculating the percentage of water required from the following formula:

$$E = \frac{3}{8} N A + 60.$$

N—Weight in grams of water required for 1,000 grams of neat cement.

A—Weight of cement in kilograms in 1,000 grams of sand mixture.

E—Weight in grams of water required for mixture.

The percentages obtained from this formula must be slightly modified, especially for the mixtures containing more than three parts standard sand. These modifications must be ascertained by experience.

STRENGTH.

The setting of cement is the change from a condition of fluidity to a solid state. When cement has set, the process of hardening is said to commence. The relative degree of hardening at any age is measured by determining its transverse, compressive, adhesive or tensile strength in pounds per square inch.

There has been no very radical change in the principles of the tension testing machines, as originated by Grant and Michaelis, although the machines are better constructed.

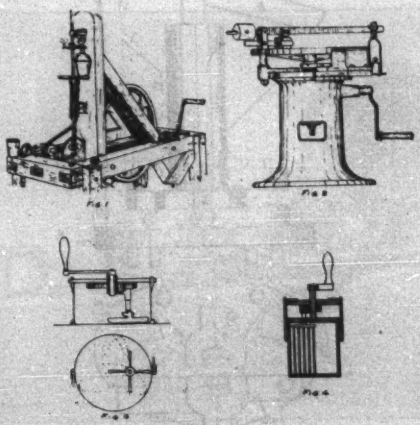

PLATE VIII—Fig. 1, Russell mixing device; fig. 2, abrasion testing machine; fig. 3, Faija mixer; fig. 4, modified Faija mixer.

Many improvements are required to make the tension tests more accurate. As a rule the Fairbanks machine is the best machine to use in making tension tests, since it is more accurate in the hands of the inexperienced than either the Riehle or the Olsen. For compression tests, the test specimens are usually 2-inch cubes.

The machine on which the compression tests are made should not be of too large a capacity, since the friction, which increases with the capacity, has an important influence

on the results of the tests, especially on cubes tested at the shorter periods of time.

The test can be made on either a regular compression machine or on the machine made by Amsler-Laffon (Plate XIX) or on the Riehlé and Olsen machines in which the usual clips for tension tests are replaced by the compression tools. The latter machines are not of sufficient capacity for testing cubes over six months old, and generally the

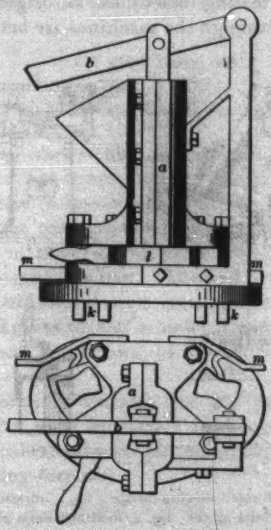

PLATE IX—Jamison molding machine.

test-specimen should be a 1-inch instead of a 2-inch cube, in order to be within this capacity. Transverse tests can be made on a compression testing machine—the test specimens should be 4 inches long and have a 2-inch section.

SECTION OF BRIQUETTE.

In tension tests, the shape of the briquette is very important.

In Plate XII are shown the various briquette sections. *Fig. 1* shows the original shape (1¼ inches section) suggested by Grant. *Figs. 2, 3* and *4* show some of his subsequent experimental forms. It is interesting to note that *Fig. 3* had a 2-inch section, while we observe that *Fig. 2* shows that holes were molded in the head and the briquette was tested by passing a pin through each hole; these pins were connected with the grips of the testing machine. The bearing against the head of the briquette being distributed by means of a flat plate.

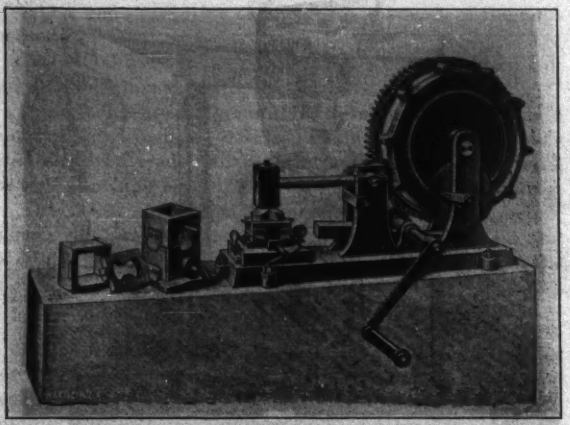

PLATE X—Boehme hammer apparatus.

In *Fig. 5* is shown the form finally adopted by Grant and one which is in general use in England at the present time.

The form adopted by the committee of the American Society of Civil Engineers is shown in *Figs. 6, 7, 8, 9* and *10*. *Fig. 11* is the form adopted by France and Germany; the section *Fig. 11* has considerably more material in the head, while an attempt is made to have the briquette break in the central section by means of the cunettes at this point. Experience does not show that this tends to increase

central section breaks, they being dependent on many other causes, the principal cause being the uniform bearing of the clips or grips of the testing machine. A variety of the grips is shown in Plate XII.

These vary from the rigid close-fitting kind shown in *Fig. 7*, to the adjustable type shown in *Fig. 10*. I prefer the type shown in *Fig. 6* without the use of rubber, thin sheet of lead, paper, or other material to give a bearing.

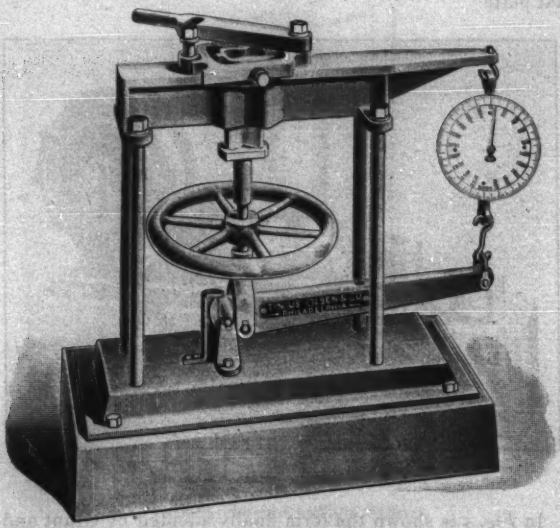

PLATE XI—Olsen molding machine.

The shape adopted by the American Society of Civil Engineers is universally used in this country, and, while not fully up to the requirements, gives fairly satisfactory results. I have found that the briquettes could be molded much more readily if the sharp corners of the American Society of Engineers' shape be rounded off with curves of $\frac{1}{8}$ inch radius.

MOLDS.

There are a number of styles of molds in use in this country, both of the single and gang type, some of which have clamps in the middle, while others have them at both ends.

The style shown in Plate VI *Fig. 6* is the most convenient and satisfactory. There should be sufficient metal in the sides of the mold so as to prevent spreading of the mold when in use. A mold which spreads produces briquettes with enlarged heads and sections, causing variations in the strength, and preventing the proper adjustment of the clips in testing.

The metal used in the molds should be brass, bronze, or some equally non-corrosive material.

Gang molds are far preferable to single molds and yield more uniform results; besides, where the number of briquettes to be made is large, the work can be done much faster by making eight or ten briquettes from one mixing.

The molds should be wiped with an oily cloth before using; this prevents the cement sticking to the mold and possibly damaging the briquette when removing from the mold.

MIXING.

About 1,000 grams of material make sufficient mortar for this number of briquettes. The French system of weights and measures is the most convenient to use. The mixing and molding should be done on some non-absorbing non-corroding surface, preferably plate glass, although marble or slate will do. If the mixing be done on a surface of marble or of slate, it will be advisable to keep this surface covered with a wet cloth when not in use, or thoroughly wet the surface previous to being used. A surface of this character, when not in use, becomes quite dry, and absorbs some of the water from the first few batches mixed on it; this renders the mortar much dryer and materially affects the results especially with sand mixtures. The material is placed on mixing slab and formed into a ring into which the proper percentage of clean water

is added. The material is turned into the ring by the aid of a trowel, and the mixing is completed by thoroughly kneading with the hands. Where the person making the test has very little experience, the mixing should last a given length of time. The German plan of mixing slow setting cement three minutes and quick setting cement one minute gives very good results. An experienced operator gauges the amount of mixing by the appearance of the paste.

This constitutes the method of hand mixing, which I have used for the last six or seven years, and have found it to be most satisfactory. Numerous mechanical mixing

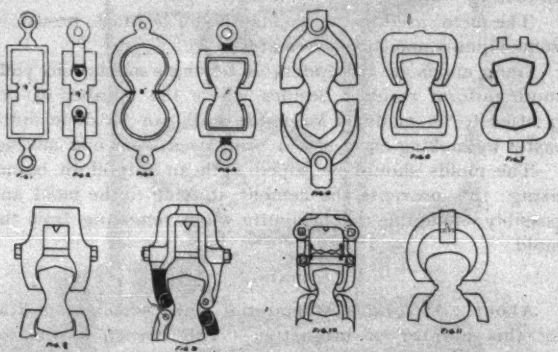

PLATE XII—Testing clips and shapes of briquettes.

machines have been devised, but the objection to them are, first, the neat cement has a decided tendency to ball, and, second, it is difficult to tell when the mixing is complete, while quick setting cements often set during the mixing. In hand mixing, the operation is under full control, and for this reason I have found the results far more uniform. Among the mechanical mixing machines may be mentioned the "Russell Jig," the "Faija Mixer," and that in use in the Cornell laboratory, a modification of the Faija mixer. Plate VIII, *Figs. 1, 3, 4*, shows some of the types of mechanical mixing machines.

The cubical box revolving at a high speed mounted on trunnions, located on the axis passing through opposite corners, gives good results with sand mixtures, but has the same defect with neat cement, viz., the tendency to ball up.

Unless the tester has considerable experience, it may be necessary for him to use one-half the quantity, especially with quick setting cements, since it is impossible to get the mortar into the molds before the mass begins to set. I have frequently seen an inexperienced person working on cement which had set and wondering why they could not get the mass into a plastic condition. When the moisture disappears from the mass and it becomes mealy and does not stick together, the cement has begun to set and should be thrown away. Many cements which appear quite dry at first, after a few minutes mixing become quite wet; this is due entirely to the kneading to which the cement is subjected.

In sand mixtures, the mixing should be thoroughly done, as this insures each grain of sand being thoroughly coated with cement. This is a very important feature in sand tests, and is the principal reason why some inspectors get so much higher results than others. Mixing machines yield much better results with sand mixtures.

The temperature of the room in which the mixing is done should be uniform and the air moist. A high temperature and dry air often produce checks in the briquettes and dries them out; this checks the process of hardening and yields low tensile strengths.

MOLDING.

Having worked the mortar to the proper consistency, it is placed at once into the molds; this is done by hand—the molding being completed by hand or by a mechanical molding device. Of the latter there are several types of which the Boehme hammer apparatus, Jamison and the Olsen machines are the best. These machines are shown in Plates IX, X and XI.

The operation of machine molding is very slow and with the present types it is only possible to mold a single bri-

quette at the time. This renders the use of a large quantity of mortar impossible, as incipient set is liable to take place during the molding, besides the moisture evaporates, rendering the mortar drier; so, as a consequence, the last briquette molded is likely to be more dense than the first.

In hand molding, the molds can be filled at once, pressed in and smoothed off with a trowel on both sides in a very few minutes. Indeed, I think greater uniformity can be secured by this rapid handling than in any other manner.

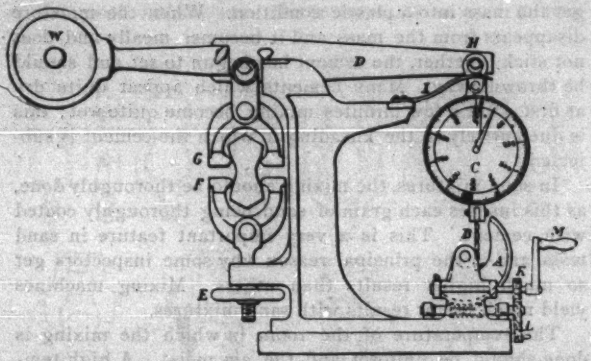

PLATE XIII—Faija testing machine.

The mortar should be heaped up on each mold and then pressed in by drawing the trowel over the surface of the mold.

The objection to the mechanical molding machines is the difficulty in securing a uniform density, due to a lack of control over the molding pressure. Again, in such machines, the pressure being applied on one surface only, renders the density unequal, the briquette being more dense on the side which received the greatest pressure.

Briquettes trowelled on both sides are far more uniform in density.

The briquettes can be marked with a soft lead pencil, or

with steel dies. If the latter are used the marking should be done on the head and not at the central section.

An excellent idea of the uniformity of the mixing and molding is afforded by weighing the briquettes before immersion in water; this is especially valuable when comparing the results of tests made by different persons.

It is the practice in some laboratories to throw out all briquettes which vary more than 3 per cent. from the mean weight.

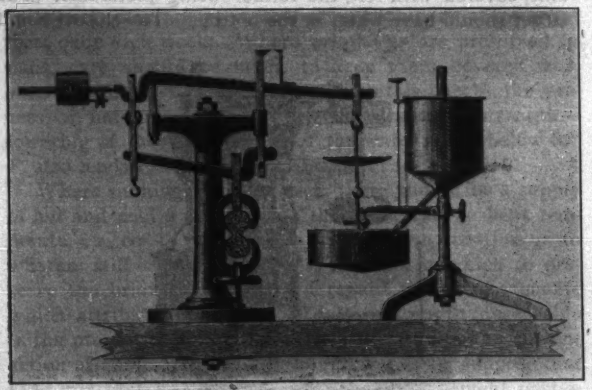

PLATE XIV—Mechalis testing machine.

PRESERVATION OF BRIQUETTES.

After the molding is completed, care should be taken to keep the briquette moist, thus preventing them from drying out. The evils resulting from this cause are shrinkage, air cracks or checks, and the retardation of the hardening; the latter being a chemical process dependent on the water used in mixing. The briquette should be sheltered from the direct rays of the sun. I have in mind an instance in which the failure of cement was traced to the morning sun shining on a portion of the mold containing the briquettes.

The briquettes should be preserved in moist air. Covering with a damp cloth is objectionable and should be avoided, as the cloth dries out in places, or the damp cloth coming in contact with the briquettes makes them too wet. In case this method is used, the cloth should be kept from direct contact with the briquettes by means of a wire screen or some similar arrangement. The most suitable method is the moist closet. This can be made of soapstone or slate, or can be a wooden box lined on the inside with zinc, covered with felt, the former being preferable. The closet should have water in the bottom. The closet should

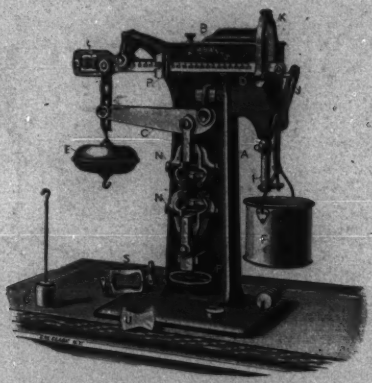

PLATE XV—Fairbanks testing machine.

also be provided with shelves on which to place the briquettes or the molds containing the briquettes. See *Engineers' Club Proc.*, Vol. XIII, No. 3.

For the twenty hour tests the briquettes should be placed in the moist closet immediately after molding, and kept there until broken; the longer time tests should be immersed in water at the end of twenty-four hours in moist air. For preserving the briquettes in water, either pans or large tanks can be used; the former should preferably be the agateware roasting pans, since there is less danger of

corrosion. The tanks can be of soapstone, and arranged as those in use in the laboratory of the city of Philadelphia, or they can be arranged as those in use in the laboratory of Lathbury & Spackman. The latter consists of a series of enamelled iron sinks arranged one over the other and supported by a frame made of wrought iron pipe; each sink being provided with a separate supply tap and an overflow pipe. (For information in connection with the city of Philadelphia laboratory mentioned above, see *Proceedings, Engineers' Club of Philadelphia*, Vol. XIII, No. 3.)

Where pans are used, the water should be renewed at least once each week. Where briquettes are preserved in pans, care should be taken to keep them covered with water, as the drying out of the briquettes checks the process of hardening and thereby impairs their strength—lowering of the temperature of the water much below 60° F. also tends to retard the hardening of the cement.

Where running water is used, there should be a supply of hot and cold water, so that the water can be kept temperate, *i. e.*, 60° to 75° F. It is still an open question as to whether still or running water is the best in which to preserve the briquettes. I do not regard the theory tenable which attributes the falling off in the strength (observable in the present high testing Portland cement) to the solvent action of running water. It would be fair to suppose that sand mixtures, having more voids than neat cement pastes, would show the greatest loss from this action. Such is not the case, however, as the loss is greater in the case of neat cement.

Again this loss is frequently observable at the end of twenty-eight days or two months; it is hardly likely that the solvent action of running water would be great enough to exert an appreciable effect in this short period of time; besides the loss is just as apparent in still water.

While it is true that cement is soluable in water, and the action may, after many years, be great enough to produce an appreciable loss of strength, yet I do not believe that the loss of strength, which is generally observable, can be attributed to this cause.

It should be borne in mind that the briquettes which show this loss of strength are quite hard, usually have a brittle fracture and show no signs of softening or of disintegration.

Running water offers many advantages over the pan method. However, the pans are less expensive and are

PLATE XVI—Olsen testing machine (hand driven).

better adapted for the laboratory on the works. Permanent laboratories should use the large tanks, which can be provided with running water or not, as desired.

BREAKING BRIQUETTES.

Briquettes should be broken as soon as taken from the water. Care should be taken to center the briquettes in

the machines, as cross strains, produced by improper centering, tend to lower the breaking strength of the briquettes. The breaking load should not be applied too suddenly, since in the Riehlé or Olsen machines this produces vibrations which tend to snap the briquette. Neat cement briquettes

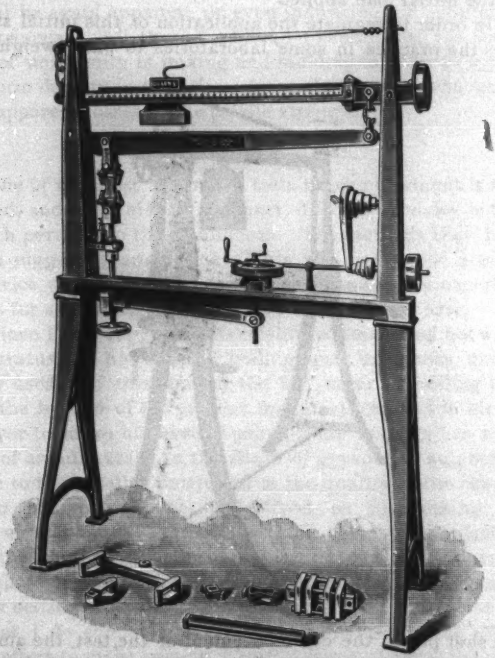

PLATE XVII—Olsen testing machine (power driven).

are often shattered by the sudden application of the breaking load, particularly if the cement be very old. The clips should be clean and the briquettes free from grains of sand or dirt, which tend to prevent a good bearing. Care should also be observed in applying the initial load; this is par-

ticularly the case with the Fairbanks machine and constitutes the chief objection to this machine. In long time tests the initial load must be very great, and, as there is no way of regulating this load satisfactorily, the variations in the results are often largely due to variations in the amount of the initial load applied.

In order to regulate the application of this initial strain, it is the practice in some laboratories to place weights in

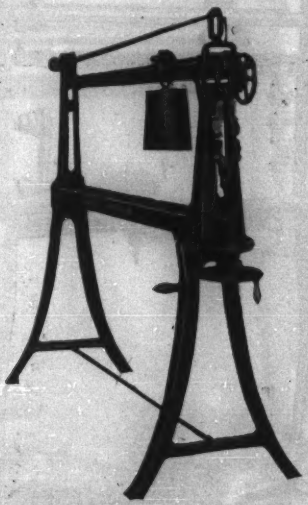

PLATE XVIII—Riehlé testing machine.

the shot pan at the commencement of the test, the amount of the weight being dependent upon the age and character (natural or Portland) of the cement under test, the weight increasing with age—it being greater for Portland than for natural cement, and also greater for neat than for sand tests.

It often happens that the last molded and usually the densest briquettes are broken at twenty-four hours or seven

days, and the first molded or less dense at twenty-eight days or longer. This difference in density may be considerable, in which case the tests may show an apparent falling off in strength. Again, the cement may begin to set before the last briquette is molded, and, should these briquettes be broken at the long time period, a loss of strength might be again apparent, or even indications of disintegrations appear. All these facts tend to emphasize the necessity of uniformity in mixing and molding in order to secure uniform density in the briquettes, and thus avoid the resultant apparent losses in the tensile strength.

CONSTANCY OF VOLUME.

One of the most important tests to which cement is subjected, and one which is the most difficult to make, is that which pertains to the soundness. The methods that have been suggested are legion. This test cannot be used by a novice with safety, and even in the hands of an expert all tests for soundness must be made with extreme care.

Since Faija suggested his celebrated steam and hot water apparatus, the hot water or boiling tests have been universally used. In this country the hot water or boiling tests are the *bete noir* of the cement manufacturer, and in his endeavor to make his cement stand these tests he has made use of an adulterant in the shape of gypsum or sulphate of lime to the possible detriment of the quality of the cement. I do not wish to be understood as condemning the use of sulphate of lime in Portland cement manufacture. On the contrary, I believe the careful and rational use of sulphate of lime is necessary in order to render this cement slow setting, and, therefore, more adaptable for general use. What I do condemn, is its present indiscriminate use in the effort to make cement "boil." Some of the other tests for determining the soundness of a cement are the high pressure steam test, the boiling test, the Michaelis hot water test, the Faija test, the cake test, the oven test, the ball test, and the kiln test; while several appliances have been devised for measuring the expansion of cement by means of rods or prisms of cement immersed in water at a normal

temperature. The standard test in Germany for constancy of volume is that of a pat of neat cement immersed in water at normal temperature for twenty-eight days. This test is not, however, sufficient to develop the unsoundness of cement in time to be of practical value.

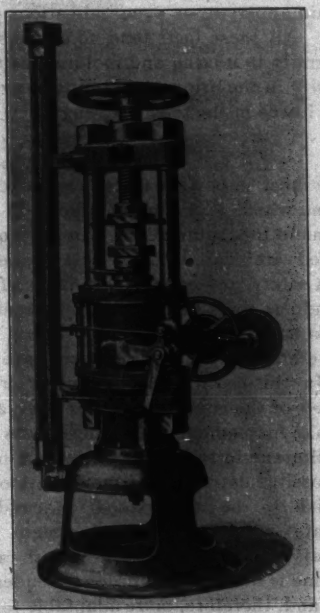

PLATE XIX.—Amsler Laffon compression machine.

I have found that usually all well-made Portland cements when made into pats and immersed in steam as soon as made, or in water (maintained a temperature not exceeding 170°) after hard set, will develop no objectionable qualities at the end of twenty-four hours, unless it be of very poor quality; such cements are also perfectly

sound in cold water. One of the difficulties encountered in these tests is in making the pats; these are made of neat cement, about three or four inches in diameter from one-quarter to one-half of an inch thick at the center and tapering to thin edges at the circumference. The pats should be made with the same percentage of water as in the case of the other tests. As simple as the making of these pats may appear to be, it is extremely difficult for

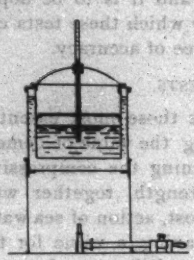

FIG. 1

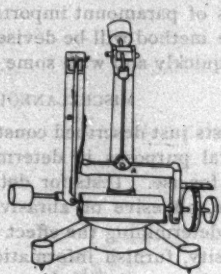

FIG. 2

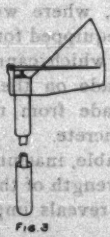

FIG. 3

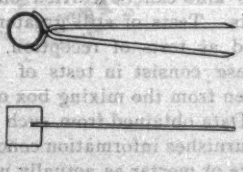

FIG. 4

PLATE XX—Fig. 1, Faija hot water apparatus; fig. 2, Bauschinger expansion apparatus; figs. 3 and 4, expansion apparatus.

inexperienced persons to make them correctly. Pats may be so trowelled as to give initial strains which develop cracks during the test. A good plan is to strike the glass on which the pat is made after molding, this rearranges the mass, drives the moisture through the pat and makes the density of the pat more uniform. Care should be taken that the pats do not dry out—this produces shrinkage

cracks, which give a false impression of unsoundness. Most pats leave the glass, and, unless this is accompanied by swelling, curvature of the pat, or cracking at the edges, it should not be taken as evidence of unsoundness. In some cases the cement may set before the pat is finished, and, when placed in steam or hot water, the outer edge may lift off—this to the inexperienced is also misleading. There is no doubt the soundness or constancy of a volume of cement is of paramount importance and it is to be hoped that some method will be devised by which these tests can be made quickly and with some degree of accuracy.

MISCELLANEOUS TESTS.

The tests just described constitute those most essential for general purposes in determining the value of cement delivered for use. Tests for determining the compressive, transverse, adhesive or abrasive strength, together with those for determining the effect of frost, action of sea water and porosity, furnish information having a value for the purposes of research, or where the conditions render such data desirable. Permanent laboratories, where work of this kind can be carried on, should be equipped for such tests. Tests of still greater importance, which cannot be used as tests of reception, are those made on the work. These consist in tests of briquettes made from mortar taken from the mixing box or cubes of concrete.

Data obtained from such tests is valuable, inasmuch as it furnishes information concerning the strength of the concrete or mortar as actually used. It also reveals improper mixing of the mortar or concrete.

[*To be concluded.*]

—*The Electro-Chemist* states that Dr. RATHENAU, of Berlin, has taken out an Austrian patent for a process of manufacturing calcium carbide of reasonable purity from materials loaded with silica by making use of the property which certain metals possess of combining with silicon in the electric furnace. Thus, when a mixture of 60 parts of anthracite containing 25 per cent. of silica is smelted electrically with 56 parts of lime and 28 parts of metallic iron, a carbide of good quality is produced, while a ferro-silicon containing 20 to 25 cent. of the latter element rests on the top of the solidified carbide and can be easily separated from it. This ferro-silicon is also capable of finding employment in the arts.

OBERLIN
COLLEGE
LIBRARY.

THE HALFTONE TRICHROMATIC PROCESS.

From a painting by W. J. McCloskey. Printed on treadle press, without overlay or other make-ready. Dill & Collins' "Trichromatic" paper.

V. 19

THE FRANKLIN INSTITUTE.

Stated Meeting, held Wednesday, November 20, 1901.

THE HALF-TONE TRICHROMATIC PROCESS.

By FREDERIC E. IVES.
Member of the Institute.

Until recently, all of the finest color printing has been done by the chromolithographic process, employing from seven to twenty stones, with as many inks and impressions, and the necessary drawings upon these stones have been made by specially trained lithographic artists.

It has long been thought by some that in accordance with the trichromatic theory of color vision, three printing surfaces, colors and impressions might be substituted for the seven to twenty of the chromolithographer and that the preparation of these surfaces might be accomplished by photography.

The only commercially successful development of this idea to-day is by the employment of three half-tone process blocks made from a trichromatic negative color record, and printed with three colored inks in the type press.

It will no doubt interest those present to know that the first public exhibition of a reproduction by this method was at the Novelties Exhibition of the Franklin Institute, in 1885.* This example was made by me in 1881, when I was the only man in the world engaged in the production of half-tone process blocks † and ten years before anybody else is known to have made a half-tone trichromatic reproduction.

The time was not then ripe for the commercial development of such a process, which demands conditions in the printing office which have been realized only after many years, by a process of evolution which was greatly stimu-

* Catalogue of the Novelties Exhibition, 1885, p. 36. See also *The Photographic News*, London, Sept. 5, 1884, first page.

† U. S. Patent No. 245, 501, Aug. 9, 1881.

lated by the introduction of the half-tone photo-engraving process.

The half-tone trichromatic process was first commercially exploited less than ten years ago, and is already a competitor of chromo-lithography, because cheaper and more direct; but the quality of the product has been, up to the present time, so uneven as to have brought the process somewhat into disrepute. This state of affairs is due largely to the fact that such success as is achieved generally depends very largely upon the degree of skill available in the correction of errors and defects in the operation of the process by re-etching the half-tone blocks—a procedure technically and appropriately known as "faking."

I have always contended that conditions could be secured which would make it possible to obtain the best results almost automatically, and it is my purpose in preparing this paper to show how this may be accomplished.

As in all other practical forms of the trichromatic process, we commence with three photographs to represent the analysis of all colors into proportions of three "primary" or fundamental colors, and it is evident that correct results cannot be obtained without the aid of hand-work unless this photographic record correctly differentiates all the hue and luminosity values of the copy. How to secure this perfect differentiation of hue and luminosity value is a problem which certainly baffled the earlier experimentors in trichromatic photography; but its solution by working to the Maxwell color curves, as first proposed by me in a paper read at this Institute in 1888,* has been sufficiently demonstrated by the results obtained in the photo-chromoscope.

In the photo-chromoscope, however, we make up our white light, not of all of the spectrum rays, but of a mixture of three practically isolated groups from the two ends and middle of the spectrum. If we were to employ all of the spectrum rays equally, but sharply divided into three groups, we should find that when we attempted to repro-

* *Journal of the Franklin Institute*, January, 1889, p. 54. U. S. Patent, No. 432,530, July 22, 1890.

duce certain hues of the spectrum, they would be somewhat degraded in purity, because pure spectrum reds, greens and blue-violets cannot be reproduced by any *mixtures* of spectrum rays. From this I have argued that color prints from Maxwell curve photographic records, if made upon paper which reflects ordinary white light, must show a little degradation of color. Comparison of such prints with the originals and with the photo-chromoscope reproductions shows that this degradation, otherwise almost unnoticeable, actually occurs and disappears when the prints are viewed in a white light made up of a mixture of isolated groups of red, green and blue spectrum rays.

From this it might be argued that the photographic color record which is suitable for one purpose is unsuitable for the other. The fact is, however, that for synthesis by any other light than the artificial white of the photo-chromoscope, no trichromatic analysis can be theoretically perfect; and I hold that the Maxwell curve analysis introduces, even for synthesis in ordinary white light, less serious errors than any other; and that the best compensation for the modicum of degradation of purity should be sought in later stages of the process, in the lining of the process blocks, the absorption and transparency of the printing inks, and the paper and press-work.

This question has been the subject of much controversy, and as it would take a volume to fully elucidate the subject, I will only add here that the demonstration which I now present is based upon Maxwell curve analysis, the results of which, under the conditions which I have secured, will speak for themselves.

The perfection of each individual element of the trichromatic negative record depends upon the relations of the source of illumination, the absorption of the selective color screen and the color sensitiveness of the photographic plate, one to another. Each of the three negatives may, however, be substantially perfect in itself, but out of key, so to speak, with the others, though being relatively less or more exposed or developed to lesser or greater density; and in the practice of the process this want of harmony of rela-

tionship is a source of error quite as serious as errors of principle in the analysis, and it is probable that two-thirds of the "faking" that is found necessary in practice is due to errors of this character, which may be introduced in any of the photographic operations, or even in the etching process, so long as the three operations are conducted separately. My cure for this difficulty consists in the production of the three images of the color record by one exposure upon a single sensitive plate, for which purpose I have devised several special cameras, one of which,* together with triple negatives produced in it, is submitted for examination. After once correctly adjusting these cameras, triple negatives can be turned out with perfect regularity, in which the relation of the images one to another, in exposure and density, is bound to be correct. The printing upon the zinc or copper-plate and the etching is also thereby reduced from three operations to one. The importance of this procedure from a labor-saving point of view is very great, because it saves much time and labor in the initial stages of the process, besides eliminating errors which frequently necessitate costly and time-consuming "faking" operations in the later stages.

In the most approved method of producing the half-tone process blocks, the half-tone process negatives are made through cross-line sealed screens, in order to translate the smooth gradations into definite line and dot, as is required by the typographic printing process. There are a few operators who employ the cross-line screen in the first instance, making the half-tone negative directly on the color-sensitive plate; but very much longer exposures are then required, and the translation of body shade into line and dot is far less definite and satisfactory than when a transparency from the smooth color record negative is made the copy for a half-tone process negative by the wet-plate process, or on special "contrast" dry plates.

My special triple cameras can be fitted with the cross-line screens, so as to make the line negatives direct; but

* U. S. Patent, No. 668,989, February 26, 1901.

after some experience of both methods I at present favor making first a triple color record, then a contact positive, and from the latter a triple half-tone process negative in the copying camera. Allowing for the saving in time in making the original exposure through color screens, no time is lost, and the half-tone process negative, made by the wet-plate process, or on a special "contrast" dry plate, is of a quality not obtainable by the first method.

Compared with the most usual procedure, fifteen operations* are thus reduced to five,† and compared with the shortest method practiced with a single camera, nine operations are reduced to five, with gain in the quality of the screen process negatives and elimination of the defects commonly introduced by separate exposure, development, printing and etching. If the screen negatives are made direct with the triple camera, the total number of operations is reduced to three.

Another reason for favoring the use of a transparency as copy for the half-tone process negative, is the fact that original triple-color records can most advantageously be made on a standard size of plate in a camera which gives images either larger or smaller than the plates required, and the images readily brought to the required size in the copying camera, when the triple half-tone process negative is made. The original triple negative is then available at any time for plates of different sizes, or with screens of different degrees of fineness, or for Kromskop slides or color print lantern slides, or for any other kind of trichromatic process reproduction which may at any future time be desired.

Three of the ruled cross-line screens are used in the copying camera in front of the one negative plate, and the arrangement is such that three small images can be made on plates of one size, or three larger images on a larger

* Three separate color-screen negatives, three separate transparencies, three separate half-tone process negatives, three separate prints on the zinc or copper-plates, and three etching operations.

† One color record negative, one transparency, one half-tone negative, one print on copper or zinc, and one etching.

plate without change of screens or alteration of adjustment. It is necessary to use three screens in order to have the lines differently disposed in the different images to avoid an offensive watered-silk pattern. This disposition of the lines at different angles to avoid this effect is seen in my original example of 1881, a copy of which I have with me, and was patented by some one else twelve years after.

By the means which I have described, sets of half-tone trichromatic printing plates may be produced with great regularity and precision, frequently requiring no re-etching to perfect them, and never any considerable amount of it. It remains only to reduce the printing to one run through the press in order to eliminate errors due to unequal inking and unequal expansion of the paper with changes of atmospheric condition, to make the production of half-tone trichromatic process reproductions as nearly as possible automatic, and of the highest average quality. Already it has been proved that the printing can be done successfully upon this principle with a special press which is now on exhibition in this city, but was not available for printing my specimens. They have been run off on an ordinary treadle press without any overlay or other "make-ready."

The depth and "openness" of the etching of the plates, and the color and transparency of the inks are very important factors in this work. To fulfill theoretical requirements, the ink must be perfectly transparent and as specifically antichromatic as possible to the respective "primary" colors in ordinary white light. If they absorb too broad bands of the spectrum, or if the blocks are not etched sufficiently open, the colors will be degraded with black—"muddied" is the technical term. If they absorb too narrow bands of the spectrum, or if the two top colors are not perfectly transparent, the superposition of the three inks will not produce a good black, and some colors must be falsely rendered. If the absorptions are diffuse, a little difference in the relative amounts of the inks put down will make great changes in the colors of the print. If the absorptions are in sharply defined bands, which meet each other over the Fraunhofer *D* and *F* lines of the spectrum, after putting down enough

to make a good black by superposition, an excess of any one will scarcely alter the colors of the print except there be lateral spreading, increasing the area of the printed lines. Inks having broadly overlapping absorptions, or not perfectly transparent, produce a quite different hue when printed in lines side by side than when the lines superpose, while perfectly transparent inks with sharply defined absorptions which just come together in the spectrum will produce a tint of almost exactly the same hue where the lines overlap and where they do not. All of these facts should be taken into consideration in the selections of printing inks, and constitute a basis for predicting what will prove most suitable.

The inks which I employ are a *minus* red (peacock blue), the absorption of which is strong and pretty even from the red end of the spectrum right up to the *D* line, but falls off to nothing in the greenish yellow; a *minus* green (crimson), the absorption of which is strong and pretty even from over the *D* line to the *F* line, falling quickly to nothing outside of those limits; a *minus* blue (yellow), the absorption of which is strong in the violet and blue, and falls off gradually between the *F* and *E* lines. A mixture of these three inks to make a transparent neutral gray, when analyzed in the spectroscope, shows somewhat more absorption in the yellow and blue-green of the spectrum than in the red, green and blue-violet parts, proving that they effect a color synthesis in some degree approximate in character to that in the photo-chromoscope, while still in bands sharp enough to make easy printing without the hue depending too much upon the flow of ink, or whether the lines or dots fall side by side or in superposition. These inks are not quite ideal, but they are the nearest approximation that I can now obtain, and they yield more accurate rendering of colors from Maxwell curve-record printing plates than the "regular" three-color process inks.

ARTIFICIAL INDIGO.

The Textile World, of Boston, devotes some space in one of its late impressions to the consideration of the new and formidable competition of natural indigo that has arisen in the synthetical indigo now placed upon the market by the Badische Anilin and Soda Fabrik, and which promises in due course of time to do for the natural product what artificial alizarine has done for the natural product derived from the madder.

The World makes the following comments on this interesting topic.

"The indigo pure (synthetic indigo) of the Badische Anilin and Soda Fabrik is nothing else but indigo, which is the same blue coloring matter as contained in natural indigo. Its properties are therefore identical in every respect with those of the latter.

"Wool, as well as cotton and silk, can be dyed with it in any vat used for indigo, and it cannot be detected even by analysis whether the natural or the artificially made indigo has been used. It consequently would be to the dyer a question of price only which of the two to employ, did not the artificial indigo possess other advantages overbalancing the natural. It is a well-known fact that natural indigo varies in strength and purity, and that the price, owing to the good or bad crops, is subject to great fluctuations.

"The synthetic indigo, on the other hand, is delivered of uniform quality and of standard strength. Fluctuations, such as occur with the natural indigo, are therefore excluded. The paste has, besides the advantage that it is sold in the ground state, thus saving grinding and being always ready for use.

"Different kinds of natural indigo are in the market; for instance, Java, containing from 70 to 80 per cent. indigotine; Bengal testing 60 to 70 per cent.; Kurpah, from 30 to 55 per cent., and even qualities below 30 per cent. In the face of such differences it is extremely difficult, and in fact almost impossible, to judge the exact coloring strength by its appearance. In analyzing, it has been found that lots sold as one quality of indigo vary in themselves, and even samples drawn from the same chest have been proven to differ as much as 7 to 8 per cent. in indigotine, though by appearance it was scarcely distinguishable.

"For some time indigotine has been extracted from natural indigo, and this product brought into the market under the name of refined indigo. Of course it is also subject to the same fluctuations in price as natural indigo itself. Efforts have also been made in India and other countries to obtain a more uniform quality in the manufacture, but it appears that the experiments have not been successful, for the qualities which are sold in the market still differ just as much as ever."

The World concludes its comments with the statement that the dyer has, when using pure indigo, a product of uniform strength, which is furnished in the form of a paste ready to use. The method of using the artificial product differs in no respect from those in vogue with the natural indigo. W.

Section of Photography and Microscopy.

Stated Meeting, held Thursday, December 5, 1901.

A NOVEL STEREOGRAM.

By Frederic E. Ives,
Member of the Section.

About sixteen years ago I was making that study of the dioptrics of half-tone screen photography which led me to devise and adopt the cross-line sealed screen and special diaphragm control now universally employed in the production of half-tone process plates. At the same time other applications of the line screen occurred to me, which I did not regard as of sufficient importance to justify me in devoting time to exploiting. One of these applications was to the production of a stereogram which should require no stereoscope or other optical aid to be seen in relief, like the ordinary double stereogram in a stereoscope.

It recently occurred to me that a very simple modification of my "Kromolinoskop" camera would enable me to produce such a stereogram, and that it might be of sufficient interest as a scientific novelty to be worthy of presentation at a meeting of this Section of the Institute.

The single example which I have found time to produce is in the form of a transparency on glass, which, when held 12 inches squarely in front of the eyes, instead of looking like a flat photograph, appears to be the front of a box within which, in full stereoscopic relief, and at different distances from the eye, are a statuette and two glass vases.

This result is obtained by placing a line screen in front of the sensitive plate in the camera, slightly separated from it, and forming the image with a 3½-inch diameter lens, behind which are two small apertures placed at the pupillary distance apart, and viewing the resulting photograph (a positive from the original negative) through a similar screen, from approximately the same distance as the focal length of the lens.

Each aperture of the lens forms an image made up of shaded lines, and, owing to difference of parallax, the lines constituting the two elements of the stereogram are separated and alternate with each other; and for the same reason, each eye picks up all of the lines belonging to the respective element of the stereogram, while the lines constituting the other element are hidden from that eye by the opaque lines of the covering screen.

In the small example exhibited, the lines of the screen are somewhat in evidence, but there is nothing to prevent the production of these pictures in such large sizes that at the proper viewing distance the lines cannot be separately perceived, and in such large sizes they would prove interesting, and might have some vogue as window transparencies, and in the production of popular illusions, such, for instance, as a magical gallery of sculpture, the statures appearing to be of life-size, and as if seen through and beyond a glass behind which there was in reality nothing but empty space.

In order to give this kind of picture a distinctive name, I propose to call them "parallax stereograms."

VENEERED DOORS.

The rapidly extending uses of hard woods have given rise to the manufacture of veneered doors. The base or core for these doors is some light wood, such as pine, etc., over which is laid a veneer of oak, birch, mahogany, or any hard wood, thus producing a door that is to all intents and purposes a hard-wood affair, combined with the lessened weight of the wood, while effectually preventing the warping and twisting that very often ruins a solid door. Such doors cost only about one-third more than a pine door.

The waste-products of sawmills are sold by the owners to a great factory in the Northwest, where they are treated and made into a "compo-board." This is in most respects superior to laths and plaster in the construction of inside walls.

The wood-pulp industry particularly commends itself to the manufacturer of furniture. He can safely say, when he turns out a lot, that he has something that will not "split" or warp. The enormous pressure to which the article is submitted effectually prevents this, and, in addition, the furniture is lighter. Thus, from one base, may be made all kinds of furniture. If you want mahogany (?) you can have it, or oak, or rosewood, walnut, ebony, and in fact any kind or style, at the same price, all due to the new industry that seems to be of unlimited applicability and value to those who cannot afford to buy furniture in the original wood.—*The Manufacturer.*

CHEMICAL SECTION.

Stated Meeting, held Thursday, October 23, 1901.

WHAT DOES THE DESIGNATION C.P. MEAN AT PRESENT?

By Lyman F. Kebler,
Member of the Section.

C.P. in the chemical world undoubtedly meant, as it should to-day, a chemical of very high purity. But the expression as used at present by the chemist, the pharmacist, physician, the photographer, the broker, etc., may mean almost anything from a chemical substance of high purity to one of very secondary quality. For ample evidence of the latter it is only necessary to read over the advertising portions of some of the journals, where can be seen some of the absurdities of the designation C.P. For example, one manufacturer advertises chemically pure tar.

That the designation C.P. may mean chemicals of ordinary purity can be seen by the following: An order was placed for C.P. zinc chloride and C.P. sodium bisulphite, two very difficult chemicals to make even of a fairly high degree of purity. What was wanted in this case were articles of good quality, "commercially pure," if you please.

Nearly all manufacturers of glycerin mark their best quality C.P. and deliver it in iron drums, supposed to be galvanized inside. If such glycerin ever was C.P. it certainly cannot be expected, in many cases, to remain so very long under these conditions. Some C.P. drum glycerin contains iron to such an extent as to render it unfit for use in mixtures which contain carbolic acid or similar chemicals. As a matter of fact, very little available glycerin answers even the U.S.P. requirements, to say nothing of C.P. These glycerins almost all contain fatty acids and substances which reduce Fehling's solution.

The photographer needs most of his chemicals of a very good quality. To many of the druggists and phy-

sicians, U.S.P. and C.P. are synonomous, and the writer has met with persons whose only criterion for C.P. was physicial appearance or a certain crystalline form. The interchanging of C.P. and U.S.P. in this way may have some *raison d'être*. The Pharmacopœia requires in a number of cases a purity of 100 per cent. which must of necessity carry with it absolute purity. A condition very rarely met with. The above authority is, however, somewhat inconsistent about its 100 per cent. purity, as the following will show: potassium bicarbonate is to be 100 per cent. pure, yet there is allowed a limit of *iron*, *chlorides*, and *normal carbonate*. Even Rochelle salt is expected to be of the above high degree of purity, but here again a limit of chlorides is prescribed.

In looking over Merck's Index for 1896 we frequently see a chemical of the same degree of purity marked both C.P. and U.S.P. A little further on the same chemical, probably of a higher purity (usually doubled and trebled in price), is marked "Guaranteed Reagent." Under these chemicals marked G.R. there is generally given a series of limit tests. For example, silver nitrate, which the present Pharmacopœia requires to be 100 per cent. pure when furnished as G.R. is permitted to be contaminated with a limit of inorganic matter. How the designation C.P. must have fallen from grace, if one of the foremost chemical manufacturers treats it with such contempt. But this is not all. The June number of Merck's Report marks only two chemicals C.P. and a slightly larger number U.S.P. These abbreviations have all been replaced with such terms as regular, pure, superior, and highest purity. Other large chemical manufacturers, like E. deHaen, Gehe & Co., Boehringer & Söhne, and others, have all generally dropped the time-honored C.P. from their price-lists. Several firms in this country still use C.P. very freely. Exactly what meaning it has to them is hard to say: for example, in one price-list is quoted sodium carbonate crystalized C.P. and sodium carbonate dry, absolutely C.P. The same list contains magnesium oxide C.P. free from sulphur, and zinc oxide C.P. free from manganese. These two chemicals are used in the estima-

tion of sulphur and manganese respectively, and while other impurities may be present, those specified above should be absent. Of what value is C.P. in such cases?

All chemists are very well aware that it is practically impossible to make an absolutely pure chemical in any quantity. Every investigator of atomic and molecular weights has encountered the difficulty of preparing absolutely pure material for his work, even in small quantities. Even the time-honored arsenic-free-zinc is hard to be secured. Most of it contains a trace of arsenic by the Marsh-Berzelius method, when permitted to act for a considerable length of time, and allowance must be made for the presence of the impurity in toxicological work.

The writer would like to see a set of standards or system of abbreviations established for chemicals and chemical compounds, so that upon proper designation the same quality would be furnished when and wherever called for. This would require the coöperation of those engaged in the various chemical industries in formulating requirements of purity for the chemicals used by them, paying attention not only to the impurities, which would interfere with the use of the chemical, but also to impurities allowable because of their non-interference.

THE WOOD-PULP INDUSTRY.

For an extended period, ever since the great impetus of paper manufacturing by the discovery that it could be used for a great many purposes besides writing upon it, experts have been constantly looking for new uses for it. The same may be said of lumber; that is, pulp lumber, that which when transformed by chemical process becomes paper. Now comes a process whereby wood-pulp is to be molded under great pressure, which is colored while in the soft condition to give rich and varied effects in paneling and frame, while receiving all the strength required in a door. The same, too, may be said of small brackets, picture molds and balustrades, which are molded hollow and with which is thoroughly incorporated a waterproof cement, with the claim that they will withstand the weather as well as terra cotta. It can be readily seen how great is the future for this branch of lumber manufacture, when one considers the use to which terra cotta is put in the construction of the great steel structures that are daily being erected in the large cities.

Pulp, molded to cover steel and iron posts, becomes almost, if not quite, non-inflammable; and in this respect will dispute with terra cotta its place

for such uses, as it can be worked up into elaborate cornices and protecting and ornamental shields at a price considerably under that of terra cotta, if the latter were molded on the same lines, and can also be so artistically finished that its general use in the decorative arts, already well begun, is only a question of time.

There is almost no limit to the uses to which wood-pulp can be put, and these will be rapidly multiplied as the supply of pine wood becomes scarcer and scarcer. The wood-pulp manufacture is also a blessing to owners of vast quantities of hitherto supposedly worthless hemlock and spruce timber, of too small a size for sawing purposes, and large quantities of "popple" and kindred wood which abounds in some portions of the North, and with which vast plains in northern and western Canada are covered, have been utilized and will be available for generations to come.—*The Manufacturer.*

THE SPARSE DISTRIBUTION OF TIN.

In one of the recent publications of the geological survey of Australasia, the writer calls special attention to the singular fact—well known to metallurgists though not to the non-expert—that tin is the most sparingly distributed metal in common use. In this respect it compares interestingly with gold, the known workable deposits of which cover 1,500,000 square miles, while the workable tin deposits are confined to less than 125,000 square miles; from which it appears that for every square mile of tin ground there are 132 square miles of gold-yielding territory. Furthermore, while there is scarcely a country in the world in which gold might not be profitably obtained, or from which it has not been obtained in the past, there are at the present time probably not more than a dozen districts in the world from which tin is obtained. The tin deposits of Cornwall famed in history as the source from which the Phoenicians obtained their tin supplies, and which have yielded immense quantities continuously down to the present, are now practically exhausted, and the same may be said of the condition of the ore deposits of Bohemia, Tuscany, Southern Spain and the Pyrenees.

In all the vast area of Asia, but two districts are known in which workable deposits of tin exist; namely, the Hunau district of China, and the Straits settlement and adjacent principalities, from the latter of which by far the largest quantity of the metal has been obtained for many years.

Thus far no workable tin deposit has been discovered in Africa. In North America at present there is not a single tin mine in operation, though promising deposits have been located in at least three widely separated localities, viz.: Virginia, Dakota and California, which, however, proved unprofitable. In Mexico extensive deposits of tin are known to exist in the province of Durango, which one day, when facilities for transportation are provided, will doubtless add greatly to the world's supply. At present, however, they remain untouched. Brazil, Bolivia and Peru in South America have paying tin ground, but the yield thus far is comparatively small, and is confined to the last-named two states. Lastly, Australasia is the source of a considerable supply of tin from lately discovered deposits in Australia and New Zealand. At present the product is only about one-tenth that of the Straits, but it is steadily increasing.

W.

A RAPID METHOD FOR DETERMINING THE VALUE OF "CHROMIC ACID" AND THE SOLUBLE CHROMATES.

By LYMAN F. KEBLER,
Member of the Section.

The principle involved in the beautiful and exact method for estimating iodine by means of sodium thiosulphate was brought forward by A. du Pasquier,* but the original method gave neither satisfactory nor concordant results. Bunsen † took up the process and pointed out the cause of its shortcomings. These researches on the volumetric estimation of iodine, in connection with Schwarz's‡ proposed use of sodium thiosulphate instead of sulphurous acid, produced a very beneficial effect on the whole domain of chemical analysis. The value of the process is not so much in the estimation of iodine in iodine compounds, but rather in the determination of such substances as will liberate iodine when brought in contact with posassium iodide, either by direct displacement (*e. g.*, the chlorinated compounds, chlorine water, bromine, etc.), or by reduction in the presence of hydrochloric acid, either with or without heat (*e. g.*, CrO_3, PbO_2, MnO_2, As_2O_5, $FeCl_3$, etc). The details of the various methods must be worked out for each substance to be estimated. If a chromate is boiled with an excess of strong hydrochloric acid, chlorine is liberated, which can be distilled and conducted into a solution of potassium iodide, contained in a suitable apparatus. The distillation may be avoided by mixing the chromate, a saturated solution of potassium iodide and the hydrochloric acid in a strong bottle provided with an accurately ground stopple. The stopple is firmly tied in, the bottle with its contents

* 1840, *An. de Chimie et de Physique*, **73**, 310; *Silliman's Jour.* **40**, 123.

† 1853 (Liebig) *Anal.*, **86**, 265–291.

‡ 1853, *Anleit. zu Maassanal., Nachträge*, 22.

immersed in water and the temperature raised to boiling, where it is kept for one hour. The bottle is then removed, cooled and the amount of liberated iodine estimated by means of N/10 sodium thiosulphate.

Both of the above methods are more or less tedious, and are liable to give abnormally high results, on account of the proneness of the hydriodic acid formed to decompose. A blank should always be carried.

F. Mohr recommends the method of decomposing the chromate with hydrochloric acid and distilling the resulting chlorine into a solution of potassium iodide. He also observes that "Die Zersetzung der chromsauren Salze durch Jodkalium in salzsaurer Loesung gibt keine konstaten Zahlen, und die Methode ist zu verwerfen." The author has not had any experience with the latter method, hence reserves comment, but the former method has given him anything but satisfactory results.

The following method has, however, been used with considerable satisfaction: Dissolve about one gram (accurately weighed) in enough distilled water to make exactly 100 centimeters. Of this solution transfer 20 cubic centimeters into a porcelain evaporating dish containing 75 cubic centimeters of water, add 2 grams of potassium iodide, 15 centimeters of 10 per cent. sulphuric acid, and mix well. Then add, from a burette, N/10 sodium thiosulphate until a distinct blue color, without yellowish cast, results, or, better, the end reaction may be determined by means of a starch solution.

It was at first thought that some time must be allowed for complete reaction of the above mixture, before the liberated iodine could be estimated, but the writer soon found that the reactions were almost instantaneous.

The reactions involved are represented by the following equations:

(1) $2\,Cr\,O_3 + 6\,KI + 6H_2SO_4 = 3\,I_2 + Cr_2(SO_4)_3 + 3\,K_2SO_4 + 6\,H_2O$.

(2) $3\,I_2 + 6\,Na_2S_2O_3 = 3\,Na_2S_4O_6 + 6\,NaI$.

(3) $K_2Cr_2O_7 + 6KI + 7\,H_2SO_4 = 3\,I_2 + 4\,K_2SO_4 + Cr_2(SO_4)_3 + 7\,H_2O$.

(4) $3\,I_2 + 6\,Na_2S_2O_3 = 3\,Na_2S_4O_6 + 6\,NaI$.

According to equations (1) and (2), one equivalent of CrO_3 requires three equivalents of $Na_2S_2O_3$, or the decinormal factor of CrO_3 is one-third of 0·009988 or 0·003329. In the same way the decinormal factor of potassium bichromate is one-sixth of 0·029378 or 0·004896.

An examination of several samples of "chromic acid" gave the following results:

Number.	Color of Crystals.	Sulphates.	Per Cent. of CrO_3.	Aqueous Solution.
1	Brownish red	Much	66·66	Clear
2	Dark crimson	None	95·71	"
3	Light brick red	60·53 per cent. calculated as $NaHSO_4$, H_2O	38·28	"
4	" " "	59·76 per cent. calculated as $NaHSO_4$, H_2O	38·89	"
5	Crimson	4·2 per cent. calculated as H_2SO_4	93·83	"

There certainly is a marked difference in the physical appearance of the above samples. No. 2 was of satisfactory quality. No. 5 was a beautiful crystalline product, and the writer was very much surprised to get a reaction for sulphates. It also gave evidence of containing a sodium salt. Nos. 3 and 4 were fairly good physically. According to the above analysis they consisted of nothing but a mixture of chromic acid and sodium acid sulphate, obtained by mixing the proper proportions of sulphuric acid and sodium bichromate; $Na_2Cr_2O_7$, $2\,H_2O + 2\,H_2SO_4 = 2\,CrO_3 + 2\,NaHSO_4 + 3\,H_2O$; then evaporating the mixture to dryness. These samples may have been intended for technical purposes, but no such information could be found anywhere on the container. It appears to be the custom of some manufacturers, however, to deliver some of their goods without the semblance of a label as to contents or quality; which appears to the writer to be a very dangerous practice.

LABORATORY OF SMITH, KLINE & FRENCH CO.

WASTE OF NATURAL GAS.

The recklessness with which Americans are prone to use or rather to misuse the products with which nature has so bountifully endowed the country is conspicuously illustrated by the manner in which the vast supplies of natural gas have been carelessly permitted to go to waste.

The State of Indiana, by reason of its geological features, is probably more favorably situated in the matter of natural gas supplies than any of the neighboring states, and the manufacturers of Indiana have availed themselves of the product more extensively than elsewhere, and to their great advantage. From a recent report of the State Geologist, it appears, however, that they will not long enjoy the benefits of this cheap and admirable fuel. He reports that the people of the State not only waste the gas in furnaces, grates and stoves, but through sheer indifference have for years been permitting the gas to escape into the air at the rate of perhaps 20,000,000 cubic feet per day, simply through neglect to cap the wells which have been bored for oil.

Already there are ominous signs of the approaching exhaustion of the gas supply. Originally the gas-producing territory embraced 3000 square miles, to-day it has shrunk to one-half this area. In the beginning of the gas era, the average gas pressure as it issued from the wells was 325 pounds to the square inch; now it does not exceed 200 pounds. During the past year the gas pressure in the center of the Indiana gas area diminished 30 pounds per square inch. Taking all the circumstances into consideration, the Geologist estimates that at the present rate of consumption, the gas supply will be practically exhausted within five years, and he even estimates that it may not last more than one year.

Oddly enough the manufacturers, who should be the most careful conservators of this product, appear to take the matter quite complaisantly, with the knowledge that they can fall back upon petroleum (of which the State is a large producer) as an efficient substitute for the gas fuel.

It is impossible to form an estimate of the enormous quantities of natural gas that have been altowed to go to waste in the oil fields of the United States since the period when deep drilling first tapped the gas reservoirs. It is within bounds to say that for every cubic foot that has been utilized a thousand have been wasted.

In its want of thought for the conservation of this overbountiful gift of nature, Indiana has only imitated the bad example of her neighbors, Pennsylvania and Ohio.

W.

The lightest solid known is said to be the pith of the sunflower, with a specific gravity of 0·028, while elder pith—hitherto recognized as the lightest substance—has a specific gravity of 0·09, reindeer's hair 0·1, and cork 0·24. For saving appliances at sea, cork with a buoyancy of 1 to 5, or reindeer's hair with one of 1 to 10, has been used, while the pith of the sunflower has a buoyancy of 1 to 35.

DARLING'S ELECTROLYTIC PRODUCTION OF METALS AND NITRIC ACID FROM FUSED NITRATES.

[*Being the report of the Franklin Institute, through its Committee on Science and the Arts, on the invention of J. D. Darling, Philadelphia. Sub-Committee: Joseph W. Richards, Chairman; C. J. Reed, H. F. Keller, Samuel P. Sadtler, Carl Hering.*]

HALL OF THE FRANKLIN INSTITUTE,

[No. 2188.] PHILADELPHIA, June 3, 1901.

The Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts, acting through its Committee on Science and the Arts, investigating the merits of Darling's Electrolytic Production of Metals and Nitric Acid from Fused Nitrates, reports as follows:

The process described and shown in operation is the electrolytic decomposition of fused sodium nitrate, producing therefrom metallic sodium and acid vapors, which are converted into nitric acid. The process is applicable to the nitrates of other alkaline metals.

Applicant's patent 517,001, of March 20, 1894, describes the continuous electrolysis of fused sodium nitrate contained in a metallic pot serving as cathode, using carbon or platinum anodes, enclosed by inverted metallic cups, which serve to collect the gases and prevent their dissemination in the electrolyte, and consequent re-combination with the liberated sodium. The arrangement of apparatus shown and method of operation described in the judgment of your committee are not such as would be conducive to high efficiency, or even admit of practical continuous working; but, since Mr. Darling, in his application for this investigation, has indicated as the particular novelties of his process, the porous cell and shunt current described in his subsequent patents, we refrain from a detailed discussion of the merits or demerits of this first patent.

Patent 590,826, of September 28, 1897, describes a porous diaphragm intended for use in a fused salt, such as the

sodium nitrate of the previous patent, and meant to increase the efficiency of the operation by preventing re-combination of the liberated ions. The great difficulty of using a material for the diaphragm which would resist the intense fluxing action of the fused salt was met by the discovery that the vitrified earthy oxides, such as pure magnesia fused in an electric furnace, were practically unattacked. The additional difficulty of forming such material into a partition was met by the device of using it as coarse powder or sand between perforated supporting walls, which may be of perforated sheet-steel.

Patent 641,276, of January 16, 1900, supplements the preceding by cheapening the material used as the filling of the diaphragm. The fused earthy oxides are costly, and applicant discovered that, contrary to expectation, a considerable proportion of Portland cement could be introduced into the partition without impairing its life, and even making a diaphragm more solid and with less tendency to crack. In such a mixture, however, ground, burned magnesite can be substituted for the more costly fused or vitrified magnesis. Improvements in the mechanical details of the construction of the cell are also shown.

Patent 641,438, of January 1, 1900, describes a complete apparatus for conducting the process, in which are shown arrangements for heating, etc., but which contains as its principal feature the novel idea of connecting the sheet-metal supporting walls of the porous diaphragm by a shunt circuit with the anode, in order to minimize the destructive action upon them of the liberated ions. When not so connected they act as "middle" or "secondary" electrodes, and a small fraction of the current liberates at their inner surface, sodium; at their outer surface, nitric-oxide gas and oxygen, and the combined effect of both ions upon these supporting walls causes their rapid destruction. By connecting them through a resistance, with the anode, they become positive, and are subjected only to the action of whatever anions may be liberated there. The statement is made that the supporting walls, with this device, have a ten-times longer life than without it.

The plant, in working operation, was very interesting. The *debris* of former types of pots and partitions gave evidence of the assiduity with which the problem had been attacked and followed up. The actual pots in operation worked without the explosions characteristic of other electrolytic sodium processes. The ladling-out of the metal was witnessed, and showed that the workmen had become familiar with the manipulations required. The current kept the electrolyte molten without the assistance of extraneous heating, except in starting. The arrangements for collecting the gases and producing nitric acid worked apparently as well as could be desired. The principal drawback to the process is the large amount of electrical power absorbed in the resistance of the porous partition, an inevitable concomitant of its use, but a disadvantage more than offset by the other features of the process, provided the process is run where power can be obtained cheaply.

Your committee admires the energy and pertinacity with which a very difficult problem has been attacked; the finding of a material which will be substantially unattacked by the fused salts used, and also act as a porous diaphragm, has been accomplished; the details of construction of the porous diaphragm have been well studied out; the idea of protecting its supporting walls by making them secondary anodes is ingenious and of practical advantage.

In view of the above conclusions, we recommend the award of the John Scott Legacy Premium and Medal to J. D. Darling, of Philadelphia, Pa.

Adopted at the stated meeting of the Committee on Science and the Arts, held Wednesday, October 2, 1901.

Attest: WM. H. WAHL, *Secretary.*

THE SAPPHIRES OF MONTANA.

Mr. George F. Kunz, the noted gem expert, in a recent publication, makes some interesting remarks on the occurrence of sapphires in Montana, which was first noticed in 1891, and appeared to be so promising that several companies were formed to mine for them systematically. The sapphire region extends for a distance of six miles along the Missouri River, the central point being Spokane Bar, about twelve miles from Helena; while another region lies about seventy-five miles east of this, centering at Yogo Gulch.

The gems of these two districts exhibit marked differences by which they may readily be distinguished. Mr. Kunz says of them: "Much beautiful material has already been obtained, but little of high value. Those from the Missouri bars have a wide range of color—light blue, blue-green, green and pink—of great delicacy and brilliancy, but not the deep shades of blue and red that are in demand for jewelry. . . . The Judith River region is more promising, the colors ranging from light blue to quite dark blue, including some of the 'cornflower' tint so much prized in the sapphires of Ceylon. Others incline to amethystine and ruby shades. Some of the more peacock-blue, and some . . . show a deeper tint in one direction than in another. Some of the 'cornflower' gems are equal to any of the Ceylonese, which they strongly resemble. W.

USES OF INFUSORIAL EARTH.

Infusorial earth, sometimes known as fossil meal, diatomaceous earth, and by other names, has of late years found numerous applications in the arts. Its principal use is in the manufacture of dynamite, the virtue of its property of absorbing and holding in suspension several times its weight of oily substances, such as nitro-glycerine. It is used also as an ingredient of soaps, the cleaning powers of which it assists principally by its mechanical action. It also affords a source of silica in the manufacture of the so-called soluble glass, or silicates of the alkalies. It is used in the manufacture of extremely light bricks and other compositions for fire-proof linings of magazines and the like, and in similar compositions as a filtering medium for water, and for other uses less important.

The *Chemical Trade Journal* mentions another suggestion in connection with the material, which is interesting: An argillaceous earth named "tfol," which contains free gelatinous silica, is largely used in Northern Africa by the Arabs as a substitute for soap in washing linen. Lahache finds that it has great capabilities of absorbing oil, one part of this substance completely absorbing five parts of heavy tar oil. When the compound is mixed with the water a perfect emulsion is formed, which does not adhere to the sides of the vessel. It is proposed to employ this earth for the purpose of emulsifying heavy tar oil for disinfecting purposes. For this purpose the tfol is first mixed with an equal weight of water, and then intimately incorporated with sufficient heavy tar oil to make a paste. W.

PROGRESS IN TELEGRAPHY.

The enormous strides that have attended the development of telegraphy during the nineteenth century are strikingly illustrated by some statistics recently issued by Sir W. H. Preece, K. C. B., late electrician to the English Post-office. In 1870 the number of words transmitted per minute was only 80; in 1890 the number had been increased to 450. In 1870, 9,850,177 messages were dispatched throughout the United Kingdom at a cost of $3,061,505, while in 1900, 89,576,961 telegrams were sent, bringing in a revenue of $17,296,765. The total number of government and private cables encircling the globe is at present 1624, covering a total length of 187,353,172 nautical miles.

MANUFACTURE AND USES OF METALLIC SODIUM.

By James D. Darling.
Member of the Institute.

Sodium is one of the most abundant of metals, and is widely distributed in nature, as silicate in felspar, as a borate in borax, as fluoride in cryolite, and especially as chloride in sea-water and rock salt, and as nitrate in Chili saltpetre. It is, of course, never found occurring naturally as metal; and, on account of its strong chemical affinity for oxygen and chlorine, its production in the metallic state has always been a more or less difficult and expensive proceeding. Although the sodium unit in common salt is worth only a small fraction of a cent per pound, even to-day, with the most improved electrical methods of manufacture, sodium is far from being what can be called a cheap metal.

It was first isolated by Davy in 1808, who obtained it by electrolyzing fused sodium hydroxide. In 1808, the electric dynamo had not been discovered, and the current developed from batteries being entirely too costly for the production of sodium on a manufacturing scale, other means were devised for separating it from its compounds. Curandau, Gay Lussac, Thenard and Deville are names intimately associated with this early stage of the metallurgy of sodium. Deville, especially, brought its manufacture to a high degree of perfection, reducing the cost of a kilo from 2,000 francs in 1855, to 10 francs in 1859. He produced it at Salindres, France, in considerable quantities, to be used in the manufacture of aluminum, by strongly heating a mixture of sodium carbonate, coal and chalk in an iron retort, and condensing the volatilized alkali metal.

No improvements of any importance were made in the methods of production until Castner, after having worked for some time at the works of the Aluminium Company in England with a modified Deville process, devised (1890) a suitable furnace, and made sodium by the Davy method of

electrolyzing fused caustic soda. Castner greatly reduced the cost of the metal and, in consequence, most of the sodium used in the arts is now made in this manner.

Many attempts have been made to make sodium electrically from the fused chloride, as that material is by far the most abundant and cheapest source of the metal, but up to the present time none of the numerous processes and furnaces patented has proven commercially successful. The high melting-point of the chloride and its strong corrosive action when in a molten state are the principal difficulties to be overcome.

Sodium nitrate and sodium hydroxide melt at 313° C. and 320° C., respectively, and there is no tendency of the sodium to volatilize at these temperatures, therefore, its collection is an easy matter. Another important point in their favor is that iron or nickel can be used for the anodes and for the containing vessels. With sodium chloride it is different. Its melting-point is about 800° C., and sodium begins to distil below 900° C., so that when the fused chloride is electrolyzed, the metal comes off mostly as a vapor, which greatly increases the difficulties of collection. It is also necessary to use carbon for the anode and the anodes and everything that has so far been tried for a containing vessel has but a short life.

In 1889, the writer, while trying to devise a practical method of electrically reducing fused sodium nitrate to nitrite, conceived the idea of making metallic sodium and nitric acid from fused sodium nitrate. On account of the stress of other work, nothing was done to develop the idea until 1894. The difficulties attending the separation of such an easily oxidizable substance as sodium from so powerful an oxidizing agent as fused sodium nitrate seemed unsurmountable, and innumerable experiments were tried before a successful method was obtained.

The experimental work was done at the works of Harrison Bros. & Co., Inc., Philadelphia, and about a year ago a twelve-furnace plant, capable of decomposing from 700 to 800 pounds of nitrate per day, was erected there to demonstrate the practical working of the process. The first form of

furnace, or electrolytic cell,* was only partly successful, but it served to emphasize what had already been recognized, viz., that to successfully separate sodium in the metallic state from a nitrate, the metal should not be liberated in contact with the fused nitrate, and there should be absolutely no opportunity for a recombination of the liberated ions to take place. This could only be accomplished by having an efficient porous diaphragm interposed between the positive and negative electrodes. The difficulty was, however, how to construct such a diaphragm. The high temperature and the destructive fluxing action of the fused electrolyte precluded the use of any of the porous diaphragms successfully used in electrolyzing aqueous solutions of salts, and it was only after a long series of disappointing trials of various substances and devices that seemed to promise a solution of the problem that the idea of a granular body of vitrified magnesium oxide, confined between walls of perforated sheet iron, was hit upon and a successful furnace constructed.

The plan ultimately adopted was to take pure magnesium oxide, fuse it to a vitreous mass in an electric furnace and, after grinding it to the proper degree of fineness, press it into a round cup having double walls of perforated sheet steel.† The porous cup thus made was 30 inches in height by 16 inches in outside diameter, with walls 4 inches thick, thus leaving the inside dimensions of the cup 26 inches deep by 8 inches in diameter. The thickness of the walls of the cup and the degree of fineness of the granular fused magnesia governed the electrical resistance, as well as the resistance to diffusion of the electrolytes, and numerous experiments were required to determine these two important factors correctly.

The rest of the furnace was very simple in construction. A cast-iron pot set in a brick furnace to contain the nitrate to be decomposed also acted as the anode, or positive electrode. A 6-inch layer of refractory insulating material was placed

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*U. S. Patent 517,001, March 20, 1894.

†U. S. Patent 590,826, September 28, 1897.

in the bottom of the pot, and the porous cup rested centrally on it, leaving a 3-inch space between the cup and the pot. This space was then filled with sodium nitrate, and the cup itself nearly filled with melted sodium hydroxide. The cathode or negative electrode, consisting of a short length of 4-inch wrought-iron pipe provided with proper electrical connections, was suspended inside the cup, reaching nearly to the bottom thereof. *Fig. 1* shows a general view of twelve such furnaces, showing the cast-iron pots imbedded in brick work; also the bridges made from wrought-iron pipe for supporting the cathodes in the porous cups.

When external heat is applied to the furnace the electrolytes melt and, permeating the walls of the cup, allow the current to pass. The result of the passage of a current of electricity of a suitable strength through such an arrangement is the decomposition of the sodium nitrate into sodium, nitrogen dioxide and oxygen. The nitrogen dioxide and oxygen are liberated as gases at the positive electrodes, and escape through the hole in the cover provided for that purpose. The positive sodium ions pass through the walls of the cup and on through the molten sodium hydroxide, to be ultimately liberated in the metallic state at the cathodes. The first sodium liberated is absorbed by, or combines with, the sodium hydroxide, hydrogen gas being evolved, and sodium monoxide probably being formed. After some time sodium rises to the top of the electrolyte in the cups, and at intervals of about one hour is dipped off with a spoon and preserved under mineral oil.

This style of porous cup and furnace gave excellent results. The use of two electrolytes of different characters, yet having a common base, allows of the sodium being liberated in a neutral medium away from all danger of oxidation by the nitrate from which it is obtained.

Various improvements have since been made in the construction of the cup. At first the perforated sheet steel walls had a very short life, being quickly eaten away by local action caused by the secondary effects of the current. This trouble was overcome by shunting about 5 per cent. of the current directly through the metal walls of the cup,

FIG. 1.—General view of sodium furnaces.

making them positive. This plan greatly reduced the local action and increased the life of the cup about ten times.*

The first cost of the electrically fused magnesia filling for the cup was very high, so a cheaper material was looked for. This was found in a mixture of ground, dead-burned magnesite and Portland cement. It is mixed with water, poured between the perforated walls of the cup, and after it has set and hardened it makes a very efficient and satisfactory diaphragm.† Reasoning *a priori* one would expect Portland cement to be readily attacked by fused sodium hydroxide and sodium nitrate, but experience has shown that it stands the fluxing action of these two substances remarkably well.

The nitrogen dioxide and oxygen evolved at the positive poles are conducted by means of earthenware pipes to a number of receivers or Woulff bottles, connected together and containing water. (See *Fig. 2*). The NO_2 gas coming in contact with the water combines with it to form nitric acid, $3NO_2 + H_2O = 2HNO_3 + NO$. The NO takes up a molecule of oxygen to again form NO_2, and more nitric acid is formed. If it is desired to make a very strong acid for use in the manufacture of high explosives, a system of towers that automatically brings the strength of the acid up to required degree is used.

Each furnace takes a current of about 400 ampères at an average E.M.F. of 15 volts. External heat is used only when starting up and when changing the cups, which have a life of 425 to 450 hours; at other times the heat generated by the resistance to the passage of the current is sufficient to keep the eleetrolytes melted. *Fig. 3* shows the switchboard with rheostats, meters, etc., for controlling and measuring the current, also the connections to the furnaces and the workmen engaged in dipping off sodium from the furnaces.

The general efficiency of the process is high, and although a higher voltage and, consequently, more power is required than is needed to decompose caustic soda, yet, on account

* U. S. Patent 641,438, January 16, 1901.
† U. S. Patent 641,376, January 19, 1901.

FIG. 2.—Apparatus for converting nitrogen dioxide into nitric acid.

of the valuable by-product of nitric acid obtained, the cost of the sodium produced is much less than when it is made from caustic soda.

Up to ten or eleven years ago about the only use for metallic sodium, outside of the laboratory, was in the manufacture of aluminum, and when the electrolytic method of making aluminum was discovered, it looked as if the production of sodium on a large scale would cease. It was only when electricity was also applied to the production of sodium that it could be produced cheaply enough to be used in fields that had hitherto been closed to it on account of its high cost. Chief amongst these new uses is the manufacture of alkaline cyanides so largely used in the extraction of gold from low-grade ores and tailings for electro-plating in photography, and other minor uses. Large amounts are also converted into sodium peroxide, to be used in bleaching wool, silk, feathers, etc., replacing the more expensive hydrogen peroxide in that work.

It is also used in making certain aniline colors and organic compounds, and wherever a powerful reducing agent is needed.

The conversion of sodium into sodium peroxide is easily accomplished by burning it in an excess of dry air, free from carbon dioxide, in a suitable externally-heated retort. On removal from the retort it is ground while still hot to a fine powder, and, as it deteriorates quickly on exposure to the air, it is packed and shipped in air-tight cans. It is a most powerful oxidizing agent, and must be handled with great care. The commercial article contains about 18 per cent. of available oxygen when fresh.

The old method of making potassium cyanide, first described by Leibig, was to take dehydrated ferro-cyanide of potassium and heat it with potassium carbonate—$2K_4Fe(CN)_6 + 2K_2CO_3 = 10\,KCN + 2\,KCNO + Fe + CO_2$. The resulting cyanide contained cyanate, but this did not materially interfere with its use. An almost pure cyanide can be obtained by heating the ferro-cyanide alone until it decomposes into potassium cyanide, nitrogen, and a compound of iron and carbon — $K_4Fe(CN)_6 = 4\,KCN + N_2 + FeC_2$.

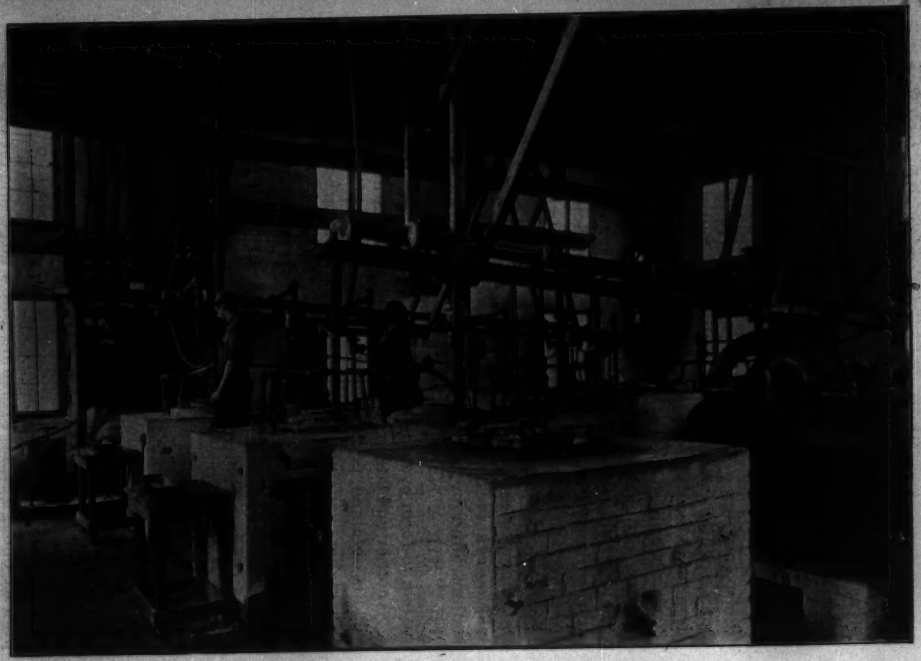

FIG. 3.—Switchboard and connections to sodium furnaces.

This method entails the loss of one-third of the nitrogen contained in the ferrocyanide, and to avoid this waste of nitrogen, Erlenmeyer proposed to add the proper amount of an alkali metal to the melted ferrocyanide—$K_4Fe(CN)_6 + 2\ Na = 4\ KCN + 2\ NaCN + Fe$. It is in this way that the most of the so-called chemically pure potassium cyanide now sold is made. The product is not a pure potassium cyanide, but a mixture of potassium and sodium cyanides. It also contains a considerable quantity of potassium carbonate, which is added to it during the course of manufacture to reduce its strength, for the combined cyanides, made according to the above formula, have a higher percentage of cyanogen than chemically pure potassium cyanide could possibly have. An inert material like potassium carbonate is therefore added in sufficient quantities to reduce the cyanogen contents to 39–40 per cent., which is equivalent to 98–100 per cent. cyanide of potassium.

Other processes have been devised for using sodium in making cyanides. One is to first convert the sodium into sodium amid by heating it in contact with ammonia gas, $Na + NH_3 = NaNH_2 + H$, then heating the amid with carbon to form cyanide $NaNH_2 + C = NaCN + H_2$.

Another and later method by which it is claimed a better yield is obtained, is to form at a temperature of about 400° C., a stable cyanamid from alkali amid and carbon, according to the formula—$2\ (NaNH_2) + C = Na_2N_2C + H_2$, then reacting the produced cyanamid with a further quantity of carbon at a temperature of 800° C. to form cyanide, according to the reaction—$Na_2N_2C + C = 2\ NaCN$. The objection to these methods is the large amount of expensive sodium metal needed for a given output of cyanide.

The writer has lately devised a process for using sodium in the synthetic production of sodium cyanide that gives good results, and in which the larger portion of the metallic base required is furnished in the form of caustic soda, and only a small amount of sodium is needed to finish the process. By this process a moderate sized sodium plant can produce enough metal to manufacture a large amount of the cyanide. The details of this new and interesting method of making sodium cyanide will be published later.

THE LIQUEFACTION OF HYDROGEN.

A note by Mr. M. W. Travers, as abstracted in the *Transactions* of the British Institution of Civil Engineers, gives an account of the method whereby the author has succeeded in obtaining liquid hydrogen in quantity. The apparatus consists essentially of a modified Hampson air-liquefier. The hydrogen, at a pressure of 200 atmospheres, undergoes a preliminary cooling —80° C. in solid carbonic acid and alcohol. It is then successively cooled by liquid air boiling under atmospheric pressure, and under a pressure of 100 millimeters, after which it escapes from the Hampson valve, and being sufficiently imperfect gas at the low temperature (—200° C.) obtained by the liquid air boiling under low pressure, regenerative cooling is produced, as in the liquefaction of air by the Hampson machine, and liquid hydrogen is obtained. It is collected in a vacuum vessel which is sepecially insulated from external heat.

BOOK NOTICES.

Practical Electric Railway Handbook. By Albert B. Herrick. Pocketbook form, pp. 407. New York: Street Railway Publishing Company. (Price, $3.00.)

The author of this work is well known to the electric railway fraternity as an expert engineer of tests in electric railway operation. He has embodied in his work above entitled the leading facts and data bearing on the efficiency of electric railway operation and has endeavored to make the subject as free from mathematical abstrusities as possible. W.

Lessons in Practical Electricity. By C. Walton Swoope. 8vo, pp. XIII + 413. New York: D. Van Nostrand Company, 1901. (Price, $2.00.)

The work above entitled originated from the need felt by the students of the Spring Garden Institute, with which the author was associated for years as an instructor, for an elementary text-book elucidating the principles of the science, and illustrating its application in practice.

The original work entitled "Lessons in Practical Electricity," fulfilled its purpose so well that the present enlarged and thoroughly revised edition has been issued. W.

Electrical Catechism. An introductory treatise on electricity and its uses. By Geo. D. Shepardson, M. E. Large 8vo, pp. 403. New York: American Electrician Company, 1901. (Price, $2.00.)

The author has endeavored to present in this volume, in non-technical language, the information sought by electrical workmen, superintendents and others employed in electrical factories, the essential principles of the science. The work should prove of very decided benefit to the class of electrical operatives. W.

Jahrbuch der Elektrochemie. Berichte über die Fortschritte des Jahres, 1900. Von Dr. W. Nernst und Dr. W. Borchers, VII, Jahrgang. 4to pp. 496. Halle a/S. Verlag von Wilhelm Knapp, 1901.

The yearbook of progress edited by Drs. Nernst and Borchers has for years been the only source of reference to the progress of the electrochemical industries available to students of this branch of applied electricity. It is simply invaluable and indispensable to all who are interested in the electrolytic and electrothermic industries. W.

The Induction Motor. A short treatise on its theory and design, with numerous experimental data and diagrams. By B. A. Behrend, M.I.C.E., etc. 8vo, pp. 105. New York: Electrical World and Engineer, Inc., N. D. (Price, $1.50.)

The author justifies the writing of this treatise by the fact that the induction motor has thus far received little attention from the authors of electrical literature—the few whose experience and knowledge of the subject would entitle them to speak authoritatively on this subject being deterred from publishing for commercial reasons.

The author treats the subject under eight chapter heads, respectively, as follows: I. The general alternating-current transformer; II (*a*) the character of the magnetic field in the polyphase motor; (*b*) the formulæ for the 3-phase-current motor; III, the short-circuit current and the leakage factor; IV, the leakage factor; V, design of a 3-phase-current motor for 200 horsepower; VI, the single-phase motor; VII, calculation of a single-phase current motor; VIII, the polar diagrams of the general alternating-current transformer. Appendices. W.

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, December 18, 1901.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 18, 1901.

President JOHN BIRKINBINE in the chair.

Present, 204 members and visitors.

Additions to membership since last month, 17.

The Secretary reported the gift of a portrait in oil of the late Joseph Harrison, Jr., well known in connection with the development of the locomotive engine, the equipment of the Russian railways, and safety steam-boiler design. The donor is Mr. Henry Harrison Suplee.

The special committee appointed at the previous meeting to consider and report upon certain preambles and resolutions "to promote commerce," offered by Prof. Louis M. Haupt, made the following report:

To the Franklin Institute.

Your committee appointed at the regular meeting of the Institute, held November 20th last, to consider the development of the rivers, harbors and other waterways of the country in order to promote both domestic and foreign commerce, and also to consider the establishment by the Government of a Department of Commerce and Industries, have given the two subjects careful consideration, and submit herewith a set of preambles and resolutions embodying the results of their deliberations.

RESOLUTIONS TO PROMOTE COMMERCE.

WHEREAS, Greater and cheaper transportation facilities are essential to the development of our domestic and foreign commerce;

WHEREAS, The limited appropriations made by the National Government are inadequate to meet the requirements of the country, covering only a small percentage of the approved projects;

WHEREAS, The former policy of authorizing the improvement of our waterways by private capital resulted in a marked development without material cost or risk to the general Government;

WHEREAS, Early and economical results may be secured by a partial return to this method in localities where no provision has been made for immediate improvement; therefore, be it

Resolved, That the proper department of the general Government should be empowered to authorize the improvement, by individuals or corporations, of such rivers, harbors, canals or other waterways as are not provided for under the River and Harbor or the "Sundry Civil" Bills, with authority to collect tolls, upon plans and regulations to be approved by the said department; *Provided*, that no part of the funds for such work shall be drawn from the public treasury of the United States. Also,

WHEREAS, The commercial and industrial interests of the country have attained such magnitude as to require a more systematic organization for their regulation and development;

WHEREAS, A measure known as Senate Bill No. 738 has been introduced into Congress for the purpose of establishing a Department of Commerce and Industries; therefore, be it

Resolved, That the establishment of such a Department of Commerce and Industries has the hearty approval of the Franklin Institute, and its early inauguration is recommended.

(Signed) THOMAS P. CONARD, *Chairman.*
LEWIS M. HAUPT,
L. Y. SCHERMERHORN.

The report was unanimously adopted, and the Secretary was instructed to send a certified copy of the same to both Houses of Congress.

General Joseph Wheeler, U.S.A., was introduced and made an address "On The Evolution of Small Arms and Ordnance," with especial reference to the improvements in automatic, rapid-fire, non-recoiling guns made by Dr. Samuel N. McClean.

General Wheeler's remarks were supplemented by Dr. McClean, who described his invention in general terms, and gave a demonstration of the capabilities of the weapon.

The address of General Wheeler was referred to the Committee on Publication, and the invention to the Committee on Science and the Arts for investigation and report.

The following nominations for officers, managers and members of the Committee on Science and the Arts were made, to be voted for at the annual election to be held on Wednesday, January 15, 1902, viz.:

For President	(to serve one year)	: JOHN BIRKINBINE.
" *Vice-President*	(" three years)	. WASHINGTON JONES,
" *Secretary*	(" one year)	. WM. H. WAHL.
" *Treasurer*	(" ")	. SAMUEL SARTAIN. .
" *Auditor*	(" three years)	WM. H. GREENE.

For *Managers* (to serve three years).

BENJ. S. LYMAN,	THOS. P. CONRAD,
COLEMAN SELLERS,	JAMES M. DODGE,
ISAAC NORRIS,	C. LELAND HARRISON,
STACY REEVES,	FRANCIS SCHUMANN.

For *Members of the Committee on Science and the Arts* (to serve three years).

HUGO BILGRAM,	LEWIS M. HAUPT,	C. J. READ,
FRANK P. BROWN,	FRED. E. IVES,	E. ALEX. SCOTT,
J. J. DE KINDER,	A. E. KENNELLY,	COLEMAN SELLERS,
W. C. L. EGLIN,	WILFRED LEWES,	H. W. SPANGLER,
A. M. GREENE, JR.,	EDGAR MARBURG,	MARTIN I. WILBERT.

Adjourned. WM. H. WAHL, *Secretary*.

SECTIONS.

(*Abstracts of Proceedings.*)

PHYSICAL SECTION.—*Stated Meeting*, November 27th, 8 P. M. Dr. Stradling in the chair.

The nomination of officers of the Section for the year 1902 was referred to a special committee composed of Mr. Wm. McClellan, Dr. Wahl and Prof. Richard Zeckwer.

Dr. A. Stanley Mackenzie presented a paper on "The Question of the Divisibility of the Atom." Discussed by Drs. Stradling, Goldschmidt, Leffmann, and Messrs. E. A. Sperry (visitor) and Pawling. (The paper is reserved for publication).

The same speakers gave the results of two investigations made at the Physical Laboratory of Bryn Mawr College. The first, by Mary J. Northway and Professor Mackenzie, was "On the Period of a Rod Vibrating in a Liquid;" the second, by Elizabeth R. Laird, was "On the Absorption Spectrum of Chlorine." Both papers were freely discussed.

Dr. Geo. F. Stradling followed with a brief résumé of some recent work in acoustics and gravitation, viz.:

E. H. Stevens has determined the speed of sound in air up to a temperature of 1000° C. by an interference method, finding it to be 700·3 meters per second.

The work of C. Sabine, which appeared in the *American Architect*, was referred to, in which the damping effect of various substances upon sound waves was determined.

Bergen Davis has found a new form of rotation produced by some waves. Four cylinders having one end open are attached perpendicularly to the ends of as many arms extending from a pivot. They are in a plane perpendicular to the axis of rotation. If this is placed in a sound wave so that the axis is parallel to the direction of the motion of the air particles, rotation takes place. By using it, nodes and loops of stationary waves can be located.

About thirty years ago Cornu and Mercadier determined the intervals between the notes occurring in a melody and seemed to show that they followed the Pythagorean scale. Zambiasi has taken up the question and concludes from his experiments that the relations in melody are those of the theoretical acoustical scale, 5/4, 5/3, etc.

The apparent change of weight occurring when chemical actions take place has once more been observed. Heydweiller finds in nearly all the reactions with which he worked a decrease in weight, the largest being 21 milligrams, when iron is in contact with basic cupric sulphate. None of the reactions was very vigorous. The reacting masses were about 200 grams.

Stated Meeting Tuesday, December 17th. Dr. Stradling in the chair.

Mr. Harvey M. Watts, of Philadelphia, presented a paper "On the Mechanism and Causation of Hot Waves," illustrating the subpart with the aid of a series of lantern slides. Discussion followed. [The paper will appear in full in the JOURNAL.]. Adjourned.

JESSE PAWLING, JR.
Secretary.

CHEMICAL SECTION.—*Stated Meeting* held Friday, November 29. Prof. Joseph W. Richards, in the chair. Present, 48 members and visitors.

It was resolved, on the recommendation of Dr. Keller, Chairman of the Executive Committee, that the stated meeting of the Section in December be omitted, and that the Section members be requested to participate instead in the Annual Meeting of the American Chemical Society which is to be held in Philadelphia in the latter part of December.

On Dr. Wahl's motion, the President of the Section was authorized to appoint a special committee to report nominations for officers for the year 1902, at the stated meeting of January.

Dr. Robt. H. Bradbury gave an account of the Goldschmidt method of reduction and the production of extremely high temperatures by the use of powdered aluminum. The special novelty of this procedure resides in the circumstance that the substances (usually mixtures of finely powdered metallic oxides with powdered aluminum) are caused to react without the aid of external heat, the reaction being initiated by the ignition of a fuse of magnesium (or its equivalent) inserted in the charge. When once started the heat developed in the reaction suffices to spread the reaction throughout the entire charge.

The speaker illustrated the process by a number of experiments showing the reduction of MnO_2, Fe_2O_3, $CaSO_4$, and numerous other interesting reactions. Of special interest was the reaction of powdered aluminum with Al_2O_3, demonstrating apparently the formation of a lower oxide; the energetic decomposition of water; and the reduction of sodium phosphate with the production of phosphorus.

Dr. H. F. Keller followed with an exhibition of a fine series of lantern slides illustrative of the history of chemistry. One series consisted of portraits of the masters of the science, and another principally of apparatus employed in epoch-making discoveries.

The speakers were given a vote of thanks and the meeting adjourned.

W. E. RIDENOUR,
Secretary.

MECHANICAL AND ENGINEERING SECTION.—*Stated Meeting* held Thursday, December 12th. Mr. A. M. Greene, Jr., in the chair. Present, 27 members and visitors.

Mr. James O. Nixon, of the Link-Belt Engineering Company, gave an account of the Renold Silent Chain Gear, illustrating the subject by specimens of the device, and by a series of views exhibiting its application for driving machinery where its advantages were specially apparent. The discussion which followed was participated in by Messrs. Fullerton, Greene, and the author.

Mr. Greene made some remarks on the so-called tangential or impulse water-wheels, illustrating the subject by the exhibition of Pelton and Dobel styles of buckets.

On Mr. Greene's suggestion a special committee was appointed to arrange for the presentation at the meetings of abstracts on current advances in engineering and the mechanical arts.

The Executive Committee was instructed to present nominations for officers for the year 1902, at the stated meeting of January 8th. Adjourned.

DANIEL EPPELSHEIMER, JR.,
Secretary.

MINING AND METALLURGICAL SECTION.—*Stated Meeting* of Wednesday, December 11th. F. L. Garrison, President, in the chair.

Mr. Wm. Campbell, of Columbia University, New York, presented a supplement to the paper of Dr. Mathews on "The Constitution of Metals and Binary Alloys." The subject was profusely illustrated with lantern slides.

G. H. CLAMER,
Secretary.

ELECTRICAL SECTION.—*Stated Meeting* held Thursday, December 19th. Mr. Morris E. Leeds in the chair. Present, 50 members and visitors.

The Executive Committee was instructed to report to the stated meeting of January a list of nominations for officers to serve for the year 1902.

Mr. Paul M. Lincoln, of Niagara Falls, presented a paper entitled, "On the Parallel Operation of Alternating Current Generators," which was freely discussed. [The paper will appear in full in the JOURNAL]. Adjourned.

THOS. SPENCER,
Secretary pro tem.